MONDAY, 09 SEPT

Oral Presentations

Can vegetation patterns and fluxes be used as indicators of disturbance and climate at different scales in Southern Europe?

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Relationships between vegetation and soil patterns ant hydrological fluxes have been studied at about fifteen locations in semi-arid and sub-humid regions of southern Europe during the last ten years. Most of the studies were undertaken in the context of land degradation or climate change impact studies. It was assumed these relationships would be sensitive to disturbance and that knowledge of them could be used to select and underpin indicators.

The presentation will firstly briefly present the methodological approach and illustrate the top-down and bottom-up data that were collected at different levels of hierarchy. It will discuss some of the difficult research issues that emerged in integrating information across scales and describe the key indicators that were selected.

The research methodology was based on hierarchy theory and on the notion of response units (at the focal scale) that were characterised by soil and vegetation patterns and by hydrological and erosion responses. At the finest scale, properties and patterns in soil aggregation (also considered at different levels of hierarchy were investigated around plants. Next at the "patch scale", relationship between soil aggregation dynamics and soil patterns and soil moisture/infiltration patterns were studied. At the slope scale, the focus was on the role of vegetation patterns on trapping water and sediment and on the effect of disturbance on the emergence of flow paths.

The research is firstly illustrated by data from field sites in the Guadalentin catchment in SE Spain Rates of change in soil properties were studied by following developments on abandoned cultivated fields. Soil aggregation/ soil depth and infiltration characteristics were closely related to vegetation patterns and these could be readily mapped on air photos.

It is concluded that relationships between vegetation patterns and for example runoff threshold rainfall intensities and sink and source areas are strongly influenced by details of the small differences in geomorphology that affect soil and nutrient water availability. In specific contexts changing vegetation patterns can be linked to degradation. Vegetation and other properties that influence emergent runoff and erosion features can be lost if vegetation cover alone is considered and not the pattern. Vegetation pattern changes can provide good indicators of climate and grazing impact provided that collateral ecological and geological information is present.

The Hydrologic Cycle and Closed Basins: From Conceptual Model to Low-Dimensional Dynamics

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The closed-basin region of the western US, aka the Great Basin physiographic province, represents a limiting case of the global water cycle. The characteristic "closed" topography and internal hydrology of this region creates a unique environment where subsurface flow and discharge to mountain-front streams are forced by orographic precipitation and basin evaporation. "Closure" in this sense means that the water cycle occurs as a "subthreshold" process, without runoff to the sea. This has been the predominant state of Lake Bonneville-Great Salt Lake for the most of the last 20k years.

In this paper, using signal decomposition methods of historical and paleo hydroclimatic records and tools of dynamical systems, the dominant time and space scales within the mountain and basin system are evaluated. Focus is on the Great Salt Lake of north-central Utah which has the longest surfacewater level record in north America (147 years). Numerical experiments demonstrate how multiple thresholds, feedbacks and nonlinearities in mountain-front, stream-groundwater systems, serve to amplify low-frequency oscillations causing relatively weak climate signals to become dominant lake- level modes. A nonlinear dynamical model is developed which exhibits stochastic resonance, or noise-induced amplification as an explanation for suprathreshold oscillations. In this case the weather is considered to be stochastic noise and climate is a weak periodic signal. The phenomenon suggests that the "noise" level (atmospheric activity) may control the large lake-level fluctuations, rather than the mean climate conditions, and that groundwater recharge and storage is an important component of the explanation. Implications for assessing long-term climate change scenarios in closed basins are discussed.

Raging runoff: quantifying obstructions to flows on semiarid hillslopes

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Runoff and sediment transport from hillslopes are, of course, natural processes. However, if hillslope runoff and erosion become excessive over a large watershed, flow-on effects downstream can be damaging, for example, the flooding of towns and cities built on floodplains and the pollution of coastal estuaries and off-shore reefs. Therefore, understanding and quantifying runoff and sediment flows from hillslopes under different conditions and disturbance regimes is important, especially in arid and semiarid regions where such flows can be extreme. A trigger-transfer-reserve-pulse conceptual framework has been used to visualize the role of obstructions, such as vegetation patches, on semiarid hillslopes to regulate flows of runoff and sediment. Field studies are quantifying such flows and how the structure, arrangement and disturbance of obstructions modifies these flows. These hillslope processes are being modelled using computer simulation techniques, and these models are being used to predict the outcomes of different disturbances and soil surface conditions on vegetation structure and on subsequent amounts of runoff and sediment transport. A 'leakiness' index based on remotely-sensed data has been developed to indicate the potential of a simple hillslope to retain sediment, with future research aimed at developing such remotely-sensed indicators for complex hillslopes at larger scales.

The role of biological soil crusts in local and landscape hydrologic cycles

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Biological soil crusts are a critical component in arid and semi-arid ecosystems. This community of cyanobacteria, fungi, lichens, and mosses cover most of the soil surfaces found between the sparse vegetation in deserts, and can thus constitute 70% or more of the living cover. Soil crusts increase soil stability, fertility, and temperature, and influence local hydrologic patterns both directly and indirectly. Because these organisms cover extensive amounts of desert surfaces, much of the water entering and leaving soils must pass through them. Therefore, they can have a direct and profound influence on local and landscape soil water relations. The relationship between crusts and soil water relations, however, is complex. The presence of organisms on the soil surface fill soil pores; this slows and decreases water infiltration.

At the same time, however, soil crusts often determine soil surface roughness which, in turn, influences the path length, tortuosity, velocity, and residence time of overland water flow on both a micro- and macro-scale. In hyperarid regions, the cyanobacterially-dominated soil crusts decrease soil surface roughness. In arid regions that lack frost-heaving of soils, effects on surface roughness are spatially patchy: where soils are exclusively cyanobacterial, soil surface roughness is decreased, whereas where lichens and mosses occur, soil surface roughness is increased. In semi-arid regions where soil frost-heaving occurs and lichen-moss cover is high, soil crusts increase soil surface roughness. Once water has entered the soil, the presence of soil surface organisms may impede evaporative loss via occupation of soil pores. At the same time, soil crusts may increase water loss due to their dark surfaces and thus increased soil temperatures. Soil crusts also influence hydrologic cycles by influencing the germination success and establishment patterns of vascular plants. The interaction of all these factors will be discussed, an integrative model proposed, and research needs highlighted.

Hot spots" for nitrogen retention in arid-land watersheds: interactions between horizontal and vertical fluxes

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In the Sycamore Creek watershed in Arizona, only 10% of annual atmospheric nitrogen inputs to the watershed are exported in streamflow. In this arid, nitrogen-limited system, where is the missing nitrogen, and which ecosystem components (terrestrial or aquatic) are responsible for its retention? Storm size and intensity are extremely variable in the Southwestern USA and may influence where and when nitrogen retention occurs. For individual storms, we monitored rainfall and runoff chemistry and volume, as well as the spatial extent of surface runoff (horizontal flux). Runoff was collected from upland slopes and within the network of intermittent rills and channels that hydrologically link the terrestrial landscape with perennial streams during storms. We also measured the potential for denitrification to occur along a topographic gradient and within the channel network in response to simulated storms (vertical flux). Results show that small storms (<0.5 cm) wet desert uplands and generated overland flow, but did not hydrologically connect the terrestrial landscape with streams. As storm size increased, the extent of flow in the channel network increased; however, only the largest storms generated flow in high-order perennial streams. This result suggests that storms interact with the landscape, generating localized "hot spots" for nitrogen retention in relation to storm size and intensity. Most of the time retention of atmospheric nitrogen is confined to terrestrial uplands. Only rare large storms transport nitrogen to perennial streams. In relation to vertical fluxes, denitrification rates were highest in surface soil/sediments, particularly in vegetated patches and riparian terraces, and rates decreased sharply with depth; however, soil moisture data indicated that these surface layers dry rapidly, while deeper layers remain wet for extended periods of time (particularly in higher order channels). Since denitrification rates are strongly influenced by soil moisture, "hot spots" may be spatially and temporally intermittent, shifting in response to local moisture conditions. Thus, we need to consider both "processing rate" and "time active" when discussing the relative importance of different locations as "hot spots" for nitrogen transformation and retention along the terrestrial-aquatic continuum. Ultimately, the extent of horizontal nitrogen transport and potential for vertical processing interact to determine where in the landscape and when nitrogen is lost, or how "hot spots" shift in space and time.

Plant water-use strategies: linking

hydrological fluctuations and physiological response.

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Recent developments in eco-hydrological theory, built around the probabilistic analysis of the soil water balance, provide a framework to study the significance of rainfall fluctuations, soil type and vegetation on the dynamics of relative soil moisture. Since soil moisture is the main controlling resource in semi-arid ecosystems, we extend this framework to consider the feedback of soil moisture on vegetation dynamics. This is achieved by providing a physiological basis for vegetation characterization, allowing us to link plant morpho-physiological traits with the soil moisture dynamics resulting from vegetation, climate and soil interactions. With the resulting model we study the probabilistic structure of carbon assimilation per unit leaf area for plants with contrasting water use strategies. We find that (1) the range of possible water-use strategies is constrained by the underlying physiological processes, so that only certain combinations of water-use characteristics are likely to occur in nature (2) according to their morpho-physiological traits, plants can be placed along a continuum between "water-spending" and "water-conserving" types, and for each particular soil type and rainfall regime there is a specific type along this continuum that has the maximum mean assimilation per unit leaf area (3) the extent to which variance in rainfall translates into variance in carbon assimilation depends on the water-use characteristics of the plant: plants with contrasting morpho-physiologies may have the same mean assimilation but with widely difference variances (4) Rainfall fluctuations have the effect of decreasing assimilation per unit leaf area for all strategies, and shifting the type that achieves maximum assimilation toward the "water-conserving" type.

Uncertainty in the sources and estimation of semi-arid runoff

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There are very many models of semi-arid runoff which assume that the infiltration excess runoff generation mechanism is dominant. There are many hydrographs from semi-arid catchments that have recession limbs with long time scales that suggest that subsurface runoff contributions might be important. There are many plot experiments that suggest that runoff coefficients for semi-arid hillslopes decrease with increasing scale. There are some tracer experiments that suggest that the average flow path length of runoff on the surface is very short. Could it be that the traditional dominance of the infiltration excess perceptual model in semi-arid conditions might need to be reconsidered? Could it be that subsurface sources of runoff on semi-arid hillslopes have been neglected in experimental work only because of the perceived dominance of the infiltration excess model? This paper attempts to evaluate the sources of uncertainty in the prediction of semi-arid runoff and outline an approach for hypothesis testing that takes account of the uncertainties of mapping the semi-arid landscape into a model space

Quantifying Spatial Heterogeneity and Covariance Between Surface Hydrologic Features and Vegetation at Multiple Scales in Semiarid Ecosystems

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In arid to semiarid ecosystems, the spatial distribution of surface properties influences how precipitation is partitioned into infiltration, runoff, and interception loss. This partitioning is critical to a variety of hydrological and ecological processes and the interactions between them. We are studying surface parameters that influence runoff and infiltration, including vegetation, microtopography and soil hydraulic properties, from the ~10 cm to hillslope scale. In semiarid shrubland and grassland, we have found that infiltration and runoff are strongly influenced by plant size and spacing, microtopography, and soil hydraulic properties, particularly soil seals. These properties differ both across and within ecosystems. For example, in the shrubland, the spatial pattern of infiltration is primarily controlled by plant size (structure) and spacing. In contrast, in the grassland, microtopography exerts a strong control on the pattern of infiltration. Based on such results, we are working to quantify the spatial variability of surface features that control infiltration and runoff. To accomplish this, we first define covariance structures between microtopography, soil hydraulic properties, and plant size and spacing at representative elementary area (REA) scales. We have found these scales, where first and second order statistics of a given feature are spatially homogenous, to be on the order of meters to tens of meters. These geostatistical models are then used to simulate spatial expectation and uncertainty fields for these parameters. This information will be used as input fields to deterministic simulations of overland flow and infiltration at the hillslope scale. Our long-range goal is to define effective parameter values (e.g., saturated hydraulic conductivity) at the hillslope scale, for use in regional scale hydrologic models, that adequately represents the fine-scale patterns of vegetation and associated properties. We expect that our methods can be applied to a range of semiarid ecosystems.

Calibration of Soil Moisture Instrumentation to Variable Soil, Temperature, and Water Content

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Obtaining accurate measurements of soil moisture is imperative for field research in ecohydrology. At present, most accurate method for monitoring soil moisture is time domain reflectometry (TDR). However, TDR is prohibitively expensive for many applications. For this reason, numerous less expensive instruments have been developed that use the same measurement principles as TDR (i.e., they measure the soil dielectric constant). The Vitel Hydra Soil Moisture Probe is one such instrument. It is currently used operationally by the Natural Resources Conservation Service and for research purposes by NASA and NOAA. At this point, no independent study of the accuracy and precision these instruments has been published. We are currently conducting combined field and laboratory studies with the Hydra probe. We have installed 19 probes in the Reynolds Creek Experimental Watershed, which illustrate the importance of extensive monitoring of soil moisture as well as the impact of temperature on sensor response. In the laboratory we are conducting studies of approximately 20 soils to determine the sensitivity of the probe to a variety of soil characteristics and a large range of temperatures. Preliminary results show that real dielectric constant is well correlated with soil moisture, however the correlation is neither the factory calibration nor the Topp equation. Under controlled laboratory settings, individual instruments were very precise-each giving uniform measurements. The research goal is to determine a calibration curve for a wide range of soil types. The poster will analyze the soil moisture data of Reynolds Creek, displaying the correlation of the measured real dielectric constant with diurnal\annual temperature fluctuations. Calibration curves from the aforementioned laboratory results will be discussed and applied to the Reynolds Creek area

Soil Water Conditions and Plant Water Use in Fore and Back Dunes of Coastal Sandy Beaches

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Sandy beaches are transitional landscapes at the interface of land and sea where environmental factors form gradients. These gradients lead to zonal patterns of plant distribution. Some authors consider it to be the result of a natural disturbance gradient that is caused by varying levels of above ground environmental factors as distance from the ocean increases, such as salt water spray, sand abrasion, and sand cover. However, underground water conditions and water sources used by plants have not been closely examined. This study investigated the hydrology of the vadose layer and water sources used by dune plants on Key Biscayne, Fl (25o55'N, 78o70'W) from July-Nov 2001. Salinity and moisture measurement of soil was combined with analysis of oxygen isotope ratios of the stem water and soil. We demarcated the zones closest to and furthest from the ocean as the fore dune (high tide mark to 15m inland) and the back dune (40-55m inland) respectively. Three soil cores were made through the vadose zone on the fore and back dune at two sampling dates and soil was collected every 25 cm (n=6/depth/position). There was an effect of soil moisture and salinity with depth at both dune positions and soil salinity was higher in the fore than the back dune at every depth in the and (MANOVA, $p<0.01$). Three replicate stems of five plant species were collected from the fore and back dune at two sampling dates (n=30/dune position). These results showed the mean d18O value of stem water from fore and back dune species was significantly different (-2.4060/00 and -3.910 0/00 respectively, t-test assuming unequal variance, $p<0.005$) and variance of d18O signal was greater for the fore dune than the back dune species (2.1 and 1.7, respectively). Absolute value of d18O means suggests that fore dune plants are, on average, using ocean water and rainwater whereas back dune plants are using rainwater and groundwater. The difference in variance of stem water between fore dune and back dune species suggests plant associations in these two habitats have different water harvesting strategies. Back dune species have three strategies, rainwater only, groundwater only and plants that utilize both water sources. The association of fore dune species in addition to utilizing the above sources of water are exposed to ocean water either by intrusion or salt spray, however individual species partition the available water resources. The stem water of two species, Sporobolus virginicus and Scavolea sericea in the fore dune, has an enriched level of d18O in stem water that suggests these plants are using some ocean water. A three-way mixing model estimated that ocean water represents 5-95% stem water for S.virginicus and 20-35% for S. sericea. These results contribute to our knowledge of the plant soil continuum of the beach habitat and factors that contribute to zonal distribution of coastal plant species. Additionally, these results may help to assess how the beach communities will respond to changes in coastal hydrology such as sea level rise, predicted by global climate models, and salinization of coastal water tables, caused by over-pumped freshwater wells.

Infiltration/Ground Water Linkages in the Southwest: Response of Shallow Ground Water to Interannual Variations of Precipitation, Jemez Mountains, New Mexico

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Hydraulic gradients, residence times and the hydrochemistry of shallow ground water are linked to the episodic precipitation and recharge events characteristic of the arid southwest. In this region, the amount of precipitation, and corresponding biomass, is dependant upon altitude with greater frequency and duration in the montane highlands and less in the desert lowlands. Results from a four-year study at the Rio Calaveras research site in the Jemez Mountains of northern New Mexico show a strong correlation between the physical and hydrochemical properties of shallow ground water and variations of seasonal precipitation and infiltration. For example, the water table shows a dramatic response to snowmelt infiltration during years of abundant snow pack (El Niño) and diminished response during years of reduced snow pack (La Niña). The chemical structure of shallow ground water is also affected by the precipitation regime, primarily by variations in the flux of reductants (organic carbon) and oxidants (dissolved oxygen) from the vadose zone to the water table. Generally, oxic conditions persist during spring snowmelt infiltration shifting to anoxic conditions as biotic and abiotic processes transform dissolved oxygen. Other redox-sensitive constituents (ferrous iron, manganese, sulfate, nitrate, and nitrite) show increasing and decreasing concentrations as redox fluctuates seasonally and year-to-year. The cycling of these redox sensitive solutes in the subsurface depends upon the character of the aquifer materials, the biomass at the surface, moisture and temperature regime of the vadose zone, and frequency of infiltration events.

In order to fully understand the complex linkages between precipitation, infiltration and shallow ground water, we are in the process of establishing monitoring stations along an east-to-west transect across the Jemez Mountains from the Rio Grand Valley to the San Juan Basin. Synoptic observations along the Jemez transect will be used to develop a conceptual model providing insight into the linkage between precipitation, hydrology and subsurface biogeochemistry at different elevations. Data from1995 to 1998 at two locations (Rio Calaveras and the Pajarito Plateu) are presented to show how shallow ground water responds to variations in precipitation at different elevations along the transect. These two locations differ by only 400 meters in elevation and are approximately 30 km apart but have different precipitation, infiltration and vegetation regimes. Differences are determined by the pattern of infiltration and runoff, character of solute transported to the upper aquifer, geomorphologic structure of the topography and the structure of the ecosystem.

A Strategy for Structuring Semiarid Landscapes to Link Processes Across Scales in Large-Scale Hydrological Models

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In semiarid environments, the dominant point-scale hydrological processes usually are evapotranspiration and infiltration-excess runoff generation. When integrating to the runoff response at the watershed scale, lateral water fluxes are often influenced by re-infiltration of surface runoff in downslope patches of different soil and vegetation characteristics. Lateral subsurface flow may be relevant for wetter conditions only, e.g., during years of above-average rainfall. The question addressed in this paper is how these dominant processes can be efficiently represented in a distributed hydrological model which should be applicable also for large watersheds, in the view of high spatial and temporal variability of climate and watershed characteristics and limited data availability.

A strategy for structuring the landscape into modeling units at various scale levels according to similarity of lateral and vertical processes is presented. Landscape units are defined which capture the structured variability of terrain characteristics varying with the position within a toposequence. Additional sub-scale variability of different soil and vegetation patches within topographic zones is represented in terms of stochastic variability. Statistical transition frequencies based on the location and fractional area of sub-units are used to represent lateral surface and sub-surface water fluxes between the modeling units.

Model applications to watersheds ranging from 0.77 km2 to 150000 km2 in size in the semiarid north-east of Brazil are presented and compared to runoff measurements. The results show that representing lateral redistribution and re-infiltration of flow components between modeling units reduces runoff considerably at the watershed scale (up to 50% for some sub-basins) when compared to simulations without lateral redistribution. Plant-available soil moisture is increased by re-infiltration of surface runoff in terrain components of downslope position in particular a certain period after the onset of the rainy season, when soil moisture in upslope areas is already high enough to generate large volumes of surface runoff while soil moisture in deeper soils of downslope position is still low enough to absorb a substantial amount of the incoming flow from the upslope region. The effect of lateral redistribution on runoff volumes at the watershed scale is more apparent in dry years as compared to wet years, leading to an overall increase in the interannual variability of runoff. This has important implications for climate change impact assessment, i.e., for the magnitude of change in discharge for an expected change in precipitation.

Current Land and Vegetation issues essential for Armenia

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The main feature of the land is its fertility, and fertile landscapes are very rare for Armenia. In Armenia land folding had lasted for hundred years with participation of rocks, water, air, temperature, vegetation, fauna and microorganisms.

By influence of water and air land undergoes erosion during which transformation of land fertile upper layer takes place representing the most problematic issues for vegetation in the country at the present.

Water erosion is caused by rain and snowmelt waters flowing down from mountain slopes that are multiply in Armenia.

As well, wind erosion occurs in result of wind blowing from not irrigated desert areas, which takes off land upper layer.

High density of soil waters leads to occurrence of marshy areas, that could be considered as pollution of land by water.

All the above mentioned is very essential for Armenian ecology, particularly land and vegetation issues.

Effects of Managed Grazing on Vegetation Structure and Range Condition in Grand Staircase-Escalante National Monument, UT: Combining Imaging Spectroscopy and Field Studies

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We used field studies and imaging spectroscopy to investigate the effect of grazing on vegetation cover in historically grazed and non-grazed high-mesa rangelands, and around a livestock watering source in the Grand Staircase-Escalante National Monument (GSENM), Utah. On grazed and non-grazed high-mesa rangelands, airborne hyperspectral remote sensing data with spectral mixture analysis (SMA) uncovered subtle but significant variations in key biogeophysical properties of arid ecosystems: the fractional surface cover of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV), and bare soil. Additionally, field measurements and SMA of remotely sensed hyperspectral imagery identified a grazing gradient around a livestock water source. Gradient persistence during a period of above-average rainfall was confirmed with multi-temporal Landsat imagery. SMA revealed a clear trend of increasing PV and NPV and decreasing bare soil with distance from water.

Sensitivity Testing of the Gap Intercept Method, a Simple, Rapid Indicator of Changes in Vegetation, Soil Erosion and Hydrologic Function

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The spatial structure of vegetation is widely recognized as a key factor controlling soil erosion and hydrology in arid and semi-arid ecosystems at multiple spatial scales. At the plant-interspace scale, shrub invasion of grasslands may cause little or no change in total plant canopy cover while dramatically increasing the area susceptible to wind erosion and reducing resistance to overland water flow. At the patch scale, the development of vegetation bands has been shown to dramatically change both hydrology and primary production. The gap intercept method is designed to detect changes in the proportion of the soil surface covered by gaps between plants larger than a minimum size. Cumulative area and frequency distributions can also be generated from the data. Gaps between both plant canopies and plant bases are recorded along the same line transect. Sensitivity tests completed in relatively degraded and undegraded areas in southern New Mexico showed that the method is sensitive to vegetation change and to related changes in wind erosion, and that it can be completed at relatively low cost by individuals with little or no botanical knowledge. We will also present the results of a comparison with a semi-quantitative "boot-gap" technique designed for use by land managers in conjunction with step-point methods of estimating plant cover and composition.

Geomorphic Influence on Ecosystem Precipitation Pulse Response in a Semi-Arid Grassland

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Rainfall pulses may be important for controlling ecological processes in semi-arid grasslands of the southwestern U.S. Responses to precipitation pulses through time at the leaf, individual plant, canopy and whole ecosystem level may not be similar across different geomorphic surfaces. Here we describe the responses of stands of native and invasive grass species to a single rainfall pulse through time across contrasting soil surfaces. We evaluated whole ecosystem CO2 / H2O dynamics, soil CO2 efflux, leaf-level gas exchange, soil H2O dynamics and aspects of canopy growth to understand potential constraints on whole ecosystem carbon dynamics. Prior to the rainfall pulse, both invasive and native grasses had less negative pre-dawn water potentials, greater rates of leaf level photosynthesis and water loss, and greater values of net ecosystem carbon exchange on a Pleistocene soil surface as compared to a Holocene surface. Immediately following the application of a pulse of rain, soil CO2 efflux increased to the point that both the native and invasive species stands lost CO2 to the atmosphere over the course of a day. Relatively greater increases in plant size and leaf level photosynthesis in the invasive species resulted in a quicker recovery of net positive ecosystem exchange relative to the response of the native species. However, the speed of this response depended upon geomorphology, with recovery occurring quicker on the Pleistocene surface. In contrast, water loss from stands was initially greater on the Holocene surfaces for both species complexes. These results suggest that complex responses of different abiotic and biotic ecosystem components control the response of whole system carbon dynamics in semi-arid grasslands. Understanding the mechanistic relationships between the soil characteristics, ecophysiological responses, and ecological dynamics will be important in understanding the effects of shifting precipitation and vegetation patterns in the southwestern U.S.

Assessing Vegetation in Relation to Sand Dune Mobilization Potential in Nebraska: A Study Using Landsat TM Data, the CENTURY Ecosystem Model, and a Digital Elevation Model.

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The Nebraska Sand Hills are a large sand dune region currently stabilized by vegetation. Long and severe droughts have the potential to kill or cause dormancy in the grasses that make up the bulk of this vegetation. We used a combination of the CENTURY ecosystem model, Landsat Thematic Mapper (TM) Normalized Difference Vegetation Index (NDVI) data at 30-m spatial resolution, and a digital elevation model (DEM) at 30-m spatial resolution to evaluate the interactions of climate, vegetation, soil, and hydrology in the Nebraska Sand Hills. A major finding was the importance of surface hydrology in vegetation's response to climate. We show that the use a digital elevation model with surface flow data complements Landsat imagery. The DEM enhances the analysis because regions that appear to be spatially homogeneous in NDVI imagery may actually be quite variable with respect to water flow and accumulation. CENTURY-simulated biomass correlates better with NDVI over large spatial areas because at very small scales, the impacts of localized water pooling and drainage that affect vegetation are cancelled out. Climatically significant events that affect ground vegetation, such as the anomalously wet year of 1993, may be reflected in Landsat NDVI values, but are not evident in the monthly CENTURY output. Wet years will cause more water flow and pooling, which is apparent in analyses using the DEM, and alters the NDVI, thus skewing the relationship between Landsat data and CENTURY-simulated biomass.

Vegetation, Climate and Soil Controls Over N Oxide Emissions From Texas Savannas

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The spatial pattern and relative abundance of herbaceous and woody plants in the savanna regions of the southwest US are dictated by complex interactions among climate, topography, soils, and land-management practices. In North Texas rangelands, encroaching mesquite (Prosopis glandulosa var. glandulosa), a known N fixing species, has caused changes in above-ground biomass, which in turn have influenced carbon and nitrogen storage in the surface soils, however, the effect of mesquite encroachment on N oxide (NO and N2O) emissions from the soils is unknown. Regional-scale quantification of the impact of vegetation change, climate and soil type on N oxide emissions was achieved through integration of high spatial resolution remote sensing data (AVIRIS), defining vegetation cover and soil type, and spatially and temporally extensive field-based measurements, establishing the abiotic (soil moisture and temperature) and biotic (vegetation type and phenology, and soil N dynamics) controls on these emissions across a gradient of above-ground mesquite biomass on two soil types. Short-term effects of precipitation on N oxide emissions were established through field wetting experiments.

Seasonally, NO emissions and nitrification potential were controlled by temperature in combination with plant growth as well as precipitation events elevating NO emissions 5X over a 24 hr period and producing small amounts of N2O. Spatially, NO emissions are controlled by co-variations in aboveground Prosopis biomass and soil type. Soil type is intimately linked to soil water holding capacity, diffusivity, and soil pH, which in combination with precipitation and temperature, control plant growth and subsequent litter decomposition, and ultimately dictate the primary controls on N oxide emissions: the supply and rate of nitrogen cycling. NO emissions were 4 times higher from clay loam soils than shallow clay soils and emissions increased 20-fold (0.4-8.7 ng m-2 s-1) across a 70-fold increase (5-350 kg m-2) in mesquite biomass. Other soil properties of pH and clay content varying in similar patterns demonstrating the integral relationship between soil parent material, climate and biology.

Resource Partitioning Within a Vegetation Sequence, Trans-Pecos Texas

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Soil moisture is frequently the resource most limiting to plant growth in arid and semi-arid regions. Resource partitioning of scarce water resources is believed to enhance vegetation production in resource sinks. The vegetation sequence described here consists of four plant communities arranged en echelon down a hillslope. Community sequence and relative herbaceous productivity suggest that runoff derived from the sodgrass (source) communities flows into and infiltrates within the bunchgrass (sink) communities. Soil, vegetation, and hydrologic data were collected from microcatchments located within four plant communities to quantify relationships between water distribution and plant cover and composition. Relative differences in runoff volume and wetting depth among the communities suggest a positive feedback relationship between plant cover and composition and infiltration. The bunchgrass communities generated significantly less runoff and were wetted significantly deeper than the sodgrass communities. Resource partitioning appeared to increase plant productivity and species richness in the bunchgrass communities. Uniformly distributed water resources might support only low value grasses such as Scleropogon brevifolius. However, additional water supplies resulting from resource partitioning allowed higher value grasses such as Setaria leucopila, Panicum obtusum, and Bouteloua curtipendula to exist in the bunchgrass communities

Flux of Particle Sizes from Burned Hillslopes

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The erosion threshold of burned hillslopes is decreased by wildfires and thus the flux of each particle size from different erosional processes is amplified. These processes are dry ravel (wind and animal activity), rainsplash, overland flow, and rill flow. Dry ravel fluxes constitute a background flux that predominates on bare hillslopes and during dry conditions. Rainsplash fluxes dominate during short duration rainstorms without overland flow but with intensities above a threshold. Overland flow dominates during longer duration rainstorms and sometimes is localized as rill flow. We installed groups of 4, 1-meter wide Gerlach sediment traps on severely burned hillslopes after the Buffalo Creek Fire in 1997 and after the Hi Meadow Fire in 2000 to collect soil eroded by these processes. Data collection after the Buffalo Creek Fire was during a wet period and most of the samples represent overland flow fluxes. Data collection after the Hi Meadow Fire in 2001 was during a mixture of short and long duration rainstorms and provide an estimate of rainsplash fluxes. Data collection in 2002 has been during a drought period and provide estimates of dry ravel

On the Ecology of Effluent?Dependent Bottomlands in the Arid and Semi-arid Southwest

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Research suggests that, all else equal, flow-regulated riverine environments depart significantly from non-regulated rivers in ecological function. Perhaps the most extreme examples of flow regulation are effluent-dependent waters, or EDWs - dry washes that have been converted to perennial streams by the introduction of treated effluent, usually municipal waste water. Enough uniqueness in EDW habitats has been revealed that EPA, Region IX awarded a grant to Pima County Wastewater Management Department to create the Arid West Water Quality Research Project (WQRP). A major research project for the WQRP has been the investigation of the physical, ecological and chemical characteristics of ten EDWs throughout the arid West. Before this investigation, a hydrological/ecological conceptual model for these unique ecosystems had not been published. We have constructed one for general review that is designed to direct future work in the WQRP. We structured the conceptual model around accepted riverine ecological concepts that build upon longitudinal continua, four-dimensional energy/nutrient exchange, feedback, and downstream spiraling and biophysical gradients. In each of these mechanisms we found important departures signaling the unique characteristics of EDW communities. In many cases, in-stream habitat values were naturally limited by substrate, downstream transmission loss, variable flow regimes, or other pre-discharge conditions. For example, the imposition of steady, perennial, effluent flow on a system graded to flashy, ephemeral, storm runoff suggests a stream that may never attain fluvial stability on a culturally-reasonable time scale. Despite these complexities, our model is designed to give terrestrial habitat equal footing with in-stream resources in ecological assessment techniques. In the arid West, where in-stream water resources are becoming increasingly limited, EDWs offer important refugia and corridors for neo-tropical migratory birds and other habitat-limited wildlife species. These beneficial uses require different hydrological tools than in-stream systems for assessing habitat health. The project investigated ten representative, yet contrasting EDW sites distributed throughout arid areas of the western US, to gather both historical and reconnaissance level field data, including in-stream and riparian, habitat and morphometric fluvial data. In most cases, the cross sectional area of the prior channel is oversized relative to the discharge of the introduced effluent. Where bed control is absent, the channels are incised downstream of the discharge point, further suggesting a disequilibrium between the channel and the regulated effluent flow. Several of the studied stream systems primarily convey storm water and are aggradational, exhibiting anastomizing channels, high energy bedforms, and spatially dynamic interfluves. Active channels are formed in response to individual storm events and can be highly dynamic in both location and cross-sectional morphology. This poses a geomorphological challenge in the selection of a discharge point. Comparing our results to numerous preconceptions about effluent-dependent ecosystems and our conceptual model has presented some important applications for research in physical ecology. Some of these potential directions will be summarized for further discussion.

An Inverse Modeling Approach to Reconstructing Plant Water Uptake Profiles

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Stable isotopes of hydrogen (D, deuterium) and oxygen (O-18) bound in plant and soil waters are useful indicators of plant-soil water interactions. Plants obtain water from various depths in the soil and the isotopic signature of stem plant water can be used to infer water sources. Simple linear mixing models have been employed to estimate the proportion of plant water uptake from different sources. These models partitions soil water into two sources (e.g., surface vs. deep) that have distinct D or O-18 signatures. However, no models are available to estimate the proportion of water acquired from multiple (> 3) sources. We take an inverse modeling approach to reconstruct plant water uptake and root area profiles for multiple soil layers. That is, we measured the D and O-18 signatures in the plant stem, which can be represented as the integral the fraction of water acquired from each soil layer, convoluted with the soil water isotope signatures of each soil layer. The model that we developed couples a statistical simulation routine, a simple biophysical model for root water uptake, and measurements of D and O-18 isotope signatures. The statistical routine places biologically realistic constraints on possible root area profiles, thereby minimizing the non-uniqueness problem. The model was successful at reproducing a variety of hypothetical water uptake profiles for the desert shrub Larrea tridentata growing in a loamy-sand soil. The algorithm is then employed to reconstruct root area and water uptake profiles for Larrea growing in the Jornada Long-Term Ecological Research (LTER) site in southern New Mexico. The model predicts that the majority (95%) of Larrea's active root area occurs in the upper soil layers (0-35 cm). The root distribution is bimodal, with 23% in the top 10 cm and 47% between 20-30 cm. This bimodality allows Larrea to take advantage of small/ephemeral summer rains that only wet the top 0-10 cm. When the surface soil is dry, Larrea actively acquires water from deeper soil layers, presumably recharged by winter rains. The algorithm presented is useful for determining how rapidly desert plants use episodic rain water and the plasticity of available water sources. These questions are important for elucidating how arid plants such as Larrea respond to rainfall variability and how sources of soil water may change due to projected shifts in rainfall patterns in arid regions.

Using fallout ^{137}Cesium estimates of soil redistribution in arid grass and shrub communities of the Northern Chihuahuan Desert

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Soil redistribution across arid landscapes is often associated with changing vegetation patterns. Arid grasslands tend to have uniform patterns of soil properties while shrublands have nonuniform patterns of soil properties. In the 1950s and 1960s radioactive ^{137}Cesium was deposited uniformly across the landscape from atmospheric fallout from nuclear weapon tests. Once in contact with the soil, ^{137}Cs is rapidly and strongly adsorbed to soil particles and any redistribution is due to the physical movement of soil particles. Thus, by measuring ^{137}Cs redistribution across the landscape, soil redistribution can be estimated. Concentrations of ^{137}Cs in soil profiles collected from grass (Black Grama and Tobosa) and shrub (Tarbush and Mesquite) sites at the USDA-ARS Jornada Experimental Range in the Northern Chihuahuan Desert in New Mexico USA were determined. At the black grama and tobosa grass sites, ^{137}Cs was uniformly distributed across the sites. At mesquite sites, ^{137}Cs was concentrated in the dune area under mesquite shrubs with little to no ^{137}Cs in the interdune areas indicating soil redistribution from the interdune space to the dune. At the tarbush sites ^{137}Cs concentration was highly variable.

Calculated erosion rates varied with vegetation type and within vegetation type. The black grama showed no net soil loss, while the tobosa site showed a net soil deposition of 5 t ha^{-1} yr^{-1}. The tarbush site had both soil erosion and deposition depending on sample location. The mesquite sites were also highly variable depending on location of the site and whether samples were taken from the dune area under the mesquite plant or from the space between dunes. Interdune areas always showed soil loss while some dunes showed gains in soil and others showed soil loss. This study shows that ^{137}Cs data from soil profiles can provide insights into the redistribution patterns of soil resources in these semiarid grass and shrub communities.

Uranium accumulation in New Mexican plant species and related soil properties

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Uranium contaminated soil due to mining activities exists worldwide in many different climatic regions. For large areas with diffuse surface uranium (U) contamination, plant uranium uptake from the soil is a potentially cost-effective remediation technique. Phytoremediation of U-contaminated soils has been explored in temperate U.S. areas, but little work has been done in more arid regions. Semi-arid soils are significantly different from those in temperate areas as they typically have higher pH and calcium carbonate content, and less organic carbon. Geobotanical studies in the Four Corners area have found evidence of uranium accumulation in native plants, suggesting their potential use for U phytoremediation in New Mexico. The purpose of this study is to identify uranium accumulators within existing New Mexico plant species, and to evaluate the relevant soil conditions.

Two abandoned uranium mine sites (with U to 10^{-3} Rem levels) northwest of Grants, NM were investigated, including gamma ray readings, percent vegetative cover, geomorphology, soil profiles and clay mineralogy. Three plant samples and a surface soil sample were collected at 64 points on 50 m grids encompassing four geomorphic areas of a mine site: undisturbed, waste piles, disturbed plains, and former drainage/ pond areas.

Results indicate three species accumulated uranium in the drainage area; two different species accumulated uranium on waste piles, and a sixth species accumulated uranium on flat disturbed ground. Soil uranium is primarily concentrated on the surface at 0-5 cm, while roots are also shallow and concentrated at 0-15 cm depth. The abundance of annual plant roots in the near-surface soils may facilitate plant accumulation of uranium in semi-arid soils. The shallow contamination and plant roots are characteristics of low water availability in upland semi-arid soils.

Groundwater - Vegetation - Atmosphere Interactions in Semiarid Riparian Ecosystems: Mesquite Eco-hydrology on the San Pedro River, Arizona

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Riparian areas within semiarid landscapes provide unique hydrological conditions for opportunistic vegetation that can utilize groundwater resources. In particular, mesquite (Prosopis spp.), commonly found on the desert floor where only recent precipitation is available as a water source, thrive also on riparian terraces by accessing more stable groundwater sources. These mesquite woodlands typically do not form closed canopies and thus allow for the co-existence of many understory plant species. In this presentation, we present above-canopy and understory energy, water and carbon dioxide flux data that provides strong evidence for a two-source-water ecosystem. The deep-rooted trees rely primarily on groundwater and the understory grasses and herbs rely on precipitation. The decoupling of water sources between the trees and the understory results in interesting and unusual hydrological (vadose zone and groundwater flows) and ecological (ecosystem water use, net ecosystem exchange, NEE) consequences.

Characterizing microbial respiration in a meander bend point bar before erosion events in a semi-arid stream, southeastern Arizona

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During summer monsoonal rains in the semi-arid southwest, major sediment scour and fill events occur. Concomitant with these changes are redistribution of microbial populations and nutrients. Microbial metabolism, which requires energy provided largely by organic carbon and nitrogen, is one key route by which nutrient transformations occur in riparian ecosystems. In this study, hydrological flowpaths and microbial respiration rates before and after leaf-out (early April) were studied in the parafluvial sediments of a stable 70-m meander bend point bar in an intermittent reach of the San Pedro River, southeastern Arizona. During this period baseflow is continuously declining in this losing reach. The point bar is characterized by coarse sands and gravels interspersed with clay layers. Two tracer injections of bromide, performed before (Feb, 2002) and after (May, 2002) leaf-out, indicated a lengthening of parafluvial flowpaths during this period. Respiration rates in parafluvial sediments to depths of 85 cm below the water table were measured in the laboratory within 18 hours of collecting sediments and oxygenated water along a flowpath. It was hypothesized that: 1) microbial respiration rates should be greatest where surface water enters the parafluvial zone, due to trapping of fine sediments and an influx of nutrients, and decline with distance along a flowpath; 2) rates should also decline with depth due to less mixing of groundwater with surface water. Results confirm the first hypothesis; respiration rates are higher at the stream-parafluvial interface compared to distances greater than a meter from the interface, 370 ± 87 $\mu g\ O_2\ L_{sed}^{-1}\ h^{-1}$ and 230 ± 50 $\mu g\ O_2\ L_{sed}^{-1}\ h^{-1}$, respectively, for sediments < 4 mm. Counter to expectations, there was only a weak statistical relationship between respiration and dissolved organic carbon and nitrogen, and fraction of sediments less than 0.85 mm. Cores taken at depth (35-50cm and 70-85cm) showed comparable respiration rates 286 ± 135 and 267 $\mu g\ O_2\ L_{sed}^{-1}\ h^{-1}$, respectively, to those taken just below the water table (2-17cm), 273 ± 80 $\mu g\ O_2\ L_{sed}^{-1}\ h^{-1}$, refuting the second hypothesis. Respiration rates did not change over this period, although the point bar became anaerobic. The lack of depth dependence suggests that respiration is important in a larger volume of the point bar than previously thought.

Spatially Distributed Model of the Potential Ecological Environments in the Western Chinese Loess Plateau

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Due to long-term and intensive human impacts on the vulnerable ecological environments of the semi-arid western Chinese Loess Plateau, this area has been degraded into nearly desert-like condition. Yet, geological and even historic data indicate that the natural ecological environments should be much better than it appears. To restore the ecological environments, we need to know its potentials. This research takes advantages of geostatistical methods and geographic information systems(GIS) and uses the digital elevation model (DEM) and observed meteorological and hydrological data to model the spatial distribution of energy balance (heat) and mass balance (water) in attempt to assess the potential natural ecological environments. Our results show that the effective soil moisture of the growing seasons is the factor that determines the potential natural ecological environments. The effective soil moisture is not only latitude- and longitude-dependent but also hydro-geomorphology-dependent. The hydro-geomorphology-dependence of the effective soil moisture has its strongest expression in steppe-forest environment. That is, in the southern part of the steppe-forest, grassland condition dominates in the hydro-geomorphologically well-drained areas, whereas in the northern part of the steppe-forest, forest condition dominates in the hydro-geomorphologically poorly-drained areas. Based on the modeled results of the air/vegetation/soil interactions in heat and water exchanges during the restoring processes of natural ecological environments, we conclude that the potential natural ecological environments should be forest and steppe-forest in the most parts of the western Chinese Loess Plateau, assuring us the confidence to restore the ecology and regain the natural beauty of the area. This research can provide the government spatially-distributed and information-enriched guidelines to scientifically plan the land uses to optimally balance the ecological and economical needs of this area.

TUESDAY, 10 SEPT

Oral Presentations

Runoff from Semiarid Landscapes: What do We Really Know?

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Not as much about runoff from semiarid landscapes is known as generally supposed. Or worse, what people think they know is based on little of no data and in many cases is probably incorrect. General conclusions have been drawn, but many of these start to fall apart when one asks more and more specific questions about specific landscapes. For example, for a given landscape, can we really answer questions as specific as, how much water runs off? What part of the landscape does water come from and where does it go? How does runoff change with scale? The answer is that without specific measurements, we can't. Much of what we think we know is based on small-plot work using rainfall simulation or point measurements of hydraulic conductivity. I would argue that by themselves, such data provide little insight into the nature of runoff at the landscape level. What is needed is measurement of naturally occurring runoff at multiple scales, from small plot to hillslope to catchment to watershed. Because this kind of work is rarely done, we don't have a good understanding of how scale affects runoff in semiarid landscapes or how those effects may be altered by disturbance. In 1993 we began a study that focuses on measurements of natural runoff at multiple scales, at three locations on semiarid ponderosa pine forests, lateral subsurface flow through a network of root-created macropores can be the dominant runoff process. In piñon-juniper shrublands, we have documented the effects of scale on runoff at slope lengths from 1 to 200 m and found that where vegetation patch structure is intact, per-unit-area runoff substantially decreases as scale increases. If a landscape has been disturbed, runoff still decreases with increasing scale, but much less precipitously. Our findings the Pajarito Plateau in New Mexico. What we found was often surprising. For example, in suggest that disturbance alters the effects of scale on runoff in a predictable way—more runoff will escape from degraded areas than from nondegraded ones. To verify these findings, more multiple-scale measurements are needed from other locations. Measurements done only at smaller scales may be of little utility, and are even misleading if they are extrapolated to apply to landscape-level situations.

Nutrient retention in stream channel and riparian hotspots of semi-arid watersheds

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Nutrient retention is a fundamental property of ecosystems that can be linked to ecosystem characteristics. Among these characteristics are hydrologic, geomorphic, and edaphic "templates", which establish the spatial and temporal distributions of hotspots of nutrient retention, owing to the creation of ideal conditions for biogeochemical processes that result in retention. For example, denitrification is a major cause of N removal that is often localized at interfaces between oxic and anoxic subsurface zones in river-riparian corridors.

Riparian zones are of management interest because they are known sites of nutrient retention in some watersheds. They have been called the nutrient filters of watersheds, particularly in agricultural landscapes where excess fertilizer leaches into groundwater which then travels to streams, encountering the riparian zone en route. However, very little is known about nutrient retention by riparian zones in arid or semi-arid systems. Long-term investigation of nitrogen biogeochemistry in unregulated streams draining Sonoran desert watersheds (Arizona, USA) provides a context for determining the relative importance of the riparian zone as a site of N retention in these ecosystems. Arid-land streams differ from their mesic counterparts in that they often exhibit declining discharge in a downstream direction, with streamflow infiltrating the bed to recharge shallow groundwater. Further, linkage between the lateral uplands and the stream-riparian corridor ecosystem may only occur during intense, short-lived storms, such that during most times of the year the terrestrial and aquatic components of these watersheds are disconnected. These features mean that 1) opportunities for retention of upland-derived N inputs may be episodic, 2) much of the N retention may occur within the stream-riparian corridor ecosystem during downstream transport, and 3) in a landscape context, overall N retention by riparian zones may be low in this arid region.

In this talk, I will explore the likely consequences of episodicity and spatial heterogeneity for larger-scale nutrient retention in arid regions. I also will ask how human-mediated changes in hydrologic regimes are likely to affect nutrient retention and change the spatiotemporal distribution of hotspots. This last, more speculative part of the talk will rely on recently initated studies of biogeochemistry in urban ecosystems.

Disturbances, thresholds, and models: A guise revealed! A call to arms!

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Semiarid/arid ecosystems often exhibit nonlinear and discontinuous responses to environmental forcings, e.g., climate and disturbance, even when the forcings themselves are continuous and gradual. Hence, it is reasonable to expect that future changes in regional and global environments will not necessarily result in smooth, linear changes in local ecosystems but, instead, we should be prepared for surprises and unanticipated outcomes. However, we're not. Many ecologists and hydrologists purport to be able to predict the future—especially when dealing with global change issues—without too many of these "surprises" appearing in the results. Do we really believe we know enough to predict the future? Future global climate change may/may not cause dramatic shifts in the distribution and extent of semiarid regions, but our ability to predict the magnitude of such shifts is limited at best. (In fact, there are a number of models for phase or regime-shifts in semiarid regions of the world but these are overwhelmingly theoretical.) Are current experimental approaches adequate to effectively reduce this uncertainty? Are the so-call "minimal but just sufficient" modeling approaches, i.e., models of highly-coupled systems that use a minimum amount of information to capture critical feedbacks and interactions, adequate to effectively reduce uncertainty? Any attempt to predict the future behavior of ecosystems, whether it is based on a mathematical model or not, is operating at the frontier of what is amenable to the scientific method today. Thus, while the application of models to study the impacts of global change on semiarid ecosystems is of value to managers and policy makers, it is also of interest to science theory, to answer the question "where are the limits of scientific predictability in complex systems?" A call to arms! Let's answer this question.

Transpiration by Mesquite on a Desert River Floodplain

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The encroachment of mesquite (Prosopis spp.) and other deeply rooted woody plants into riparian floodplains has the potential to alter local and regional water balance of desert basins in southwestern North America. To address this, we estimated seasonal water use of mesquite at a woodland site on the upper San Pedro River in southeastern Arizona. Sap flow was measured on trees ranging in basal diameter from 10 to 75 cm. Stand transpiration was scaled from these sap flow measurements and basal diameter per ground area relationships. Transpiration was highest in June (pre-monsoon), declined 60% by July (peak monsoon), and declined even further by the end of the monsoon (September). Daily total transpiration was correlated to potential evapotranspiration (PET) over the growing season. Over a diurnal period, transpiration was correlated to PET only during the morning hours and declined in the afternoon when PET was highest. Leaf predawn water potential (Y) showed that trees had access to a stable source of water before and during the monsoon, but water became more limiting by

September. There was no relationship between tree size and Y, indicating that even the smallest trees had access to the stable source of water during the driest period before the onset of monsoonal rains. Taken together, our data suggest that shifts in vegetation cover from grassland to woodland will have significant impacts on the water balance of semi-arid riparian ecosystems.

Soil Carbon and Nitrogen Heterogeneity: Combining Spatially Explicit Data and Spatially Interactive Models in the Urbanized Sonoran Desert

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The central question my research is: how do ecological, hydrological, and sociological processes affect soil carbon and nitrogen storage at multiple scales in the central Arizona-Phoenix (CAP) region? Three classes of interacting factors are likely to dominate spatial variability of biogeochemical elements: vegetation nutrient sequestration from surface runoff into islands of fertility, hydrologic flow-paths inducing nutrient movement down-slope, and human modification of community composition as well as hydrologic and nutrient fluxes. Because the constraints to hydrologic nutrient redistribution and ecosystem nutrient storage are scale dependent, I am studying soil heterogeneity at multiple scales. At the plot-scale, I am synthesizing information on specific plant-soil-water interactions. Processes at the site-scale emphasize the dynamic spatial relationships between individual plant and bare ground patches connected primarily through hydrological flows. Currently, I am analyzing six replicated site-scale surveys of soil nutrient spatial variability, focusing upon carbon and nitrogen. The sites for these surveys were chosen to characterize the potential differences in ecological and hydrological interactions in the CAP region; the sites include mesic residential, native desert, and agricultural areas. At the regional-scale I am examining the spatial variability in soil components collected by the CAP-LTER synoptic survey of Phoenix metro-region. Combined, the broad scale survey and the replicated fine scale surveys describe how fine scale mechanisms and broad scale constraints create the existing spatial mosaic. In conjunction with these empirical descriptions of spatial heterogeneity I am implementing spatially interactive mechanistic biogeochemical models describing soil carbon and nitrogen variability. This modeling work is developing theoretical predictions of horizontal nutrient distribution in urbanized semiarid ecosystems that will be directly compared to the empirical analyses.

Vertical water fluxes control carbon and nutrient cycling in semiarid ecosystems

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Vertical water fluxes control the magnitude of carbon and nutrient cycling in arid and semiarid ecosystems by interacting with soil texture and plant species morphological characteristics. Soil texture determines the depth of the soil layer that is most frequently wet and the magnitude of competing soil-water losses in arid and semiarid ecosystems, evapotranspiration and deep percolation. The inverse-texture hypothesis relates precipitation and soil texture to primary production. An extensive data set from the Great Plains of the US supported the inverse-texture hypothesis with higher production in coarse texture soils in sites where annual precipitation was below 370 mm per year. On the contrary, above 370 mm per year, fine-textured soils had higher production than coarse texture soils.

Vertical fluxes interact with plant-morphological constraints and determine patterns of carbon gain of different life forms. In the Patagonian steppe, shrub species have deeper roots and use infrequent pulses of water availability, which last for long periods of time. On the contrary, grasses have shallow roots and utilize short-duration and frequent pulses of water availability. Finally, field experimentation coupled with simulation models showed that global change would result in an alteration of the vertical fluxes of water and consequently changes in carbon and nutrient cycling. Elevated CO_2 would result in a reduction of evapotranspiration and an increase in deep percolation, an increase in water-use efficiency, and a change in the balance between shrubs and grasses and between early and late season species.

TUESDAY EVENING

Poster Presentations

Impacts of Disturbance on Runoff and Nutrient Fluxes from Biologically Crusted Soils

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In this study we conducted a rainfall simulation experiment to examine the impact of soil surface disturbance (defined here as trampling) on runoff and nutrient fluxes from biologically crusted soils. To separate the effect of disturbance on biological soil crust cover from trampling effects on subsurface soil physical structure, we compared runoff and nutrient fluxes from intact biological soil crusts (Control) to both trampled biological soil crusts where we made 100 passes over a 0.5 m2 plot (Trampled) and biological soil crusts where we removed the top 1 cm of the soil surface but the subsurface physical structure was left intact (Scraped). Infiltration rates were lower in trampled plots relative to scraped and controls. The decrease in infiltration rates was most likely due to changes in soil compaction where trampling resulted in a 15% increase in bulk density. Total organic carbon (TOC) flux from trampled plots was significantly greater than scraped plots, but was not significantly different than controls [Mean TOC flux mg/m2; Trampled = 61, Control = 45, Scraped = 37]. Although we observed no large differences in total nitrogen flux in runoff, there were significant differences in NO3- flux. Control plots appeared to retain small amounts of NO3- whereas the scraped and trampled treatments always resulted in a positive NO3- flux [Mean NO3- flux mg/m2; Trampled = 0.59, Control = -0.05, Scraped =1.16]. Sediment yield from trampled plots was 4 times higher than control plots with no significant difference compared to scraped plots. However we observed no significant differences in sediment yield between scraped and controls. Overall, change in subsurface soil physical structure appears to be the most important factor controlling infiltrations rates, sediment yield and C fluxes in runoff. However, biologically crusted soil plays a greater role in retention of inorganic N.

Modelling Runoff in Semi-Arid Areas from the Hillslope to the Watershed Scale

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A series of nested experiments was carried out to monitor the flux of runoff after intense, natural rainfall events at a range of scales in the semi-arid south western US. Data from these experiments were used to validate a distributed, dynamic, process-based model, previously shown to perform well at the plot scale on semi-arid shrubland. To extend previous work, the model was applied to sites ranging in size from 2m2 up to 2km2 to investigate model response to changes in scale and to provide a means of linking predictions made at the hillslope scale with those made at the catchment scale. Results indicate that given high quality input data accurate predictions can be made at a range of hillslope lengths. Furthermore, hydrographs observed from a series of 7 nested catchment areas are reproduced permitting confidence in model upscaling and spatial validation of model output. Limitations focus upon high data requirements, though remote sensing techniques are being developed to reduce time spent on data capture of surface condition parameters. Future efforts will concentrate on the addition of sediment entrainment and routing algorithms and the validation of sediment flux predictions also observed during the aforementioned experiments

Vertical and horizontal heterogeneity in plant available water: trends from a semiarid woodland

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The pattern and dynamics of soil water availability is a fundamental component of the co-hydrology of semiarid ecosystems. However, data on long-term variability in soil water availability is largely lacking, particularly with respect to how it varies spatially, horizontally as well as vertically. We measured soil water content using neutron probe over a 14-year period in a piñon-juniper woodland at the Mesita del Buey Research Site in northern New Mexico. Our objectives included assessing (1) the amount of precipitation from small vs. large precipitation events in wet vs. dry years; (2) the temporal variability of soil water, both as a function of depth and as a function of cover (canopy) patches beneath trees, intercanopy patches between trees, and edges between the two patch types); and (3) implications for the vertical and horizontal distributions of plant-available water. Our results highlight (1) the inter-annual stability of the amount of precipitation resulting from small events in contrast to high inter-annual variability in the amount of precipitation resulting from large events, (2) large temporal variations in soil water availability, driven largely by differences in winter precipitation, and (3) the potential importance of considering horizontal as well as vertical heterogeneity in soil moisture. Overall, these results highlight the spatial and temporal dynamics of soil water availability and suggest that horizontal heterogeneity in soil water availability may be more important than previously appreciated.

Soil Degradation and Hydrologic Response at the National Training Center (NTC), Ft. Irwin, California.

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Military training exercises at the National Training Center (NTC), Ft. Irwin, California have led to the degradation of large areas of soil cover. Revegetation of these lands by the Integrated Training Areas Management (ITAM) Program requires identification of optimum growing conditions based on the character of the desert soil and the landscape position; hence land managers need a quantifiable measure of soil degradation. Soil hydrology is considered the major catalyst to seedling reestablishment in arid environments where water is typically the limiting factor. Soil hydraulic properties at interspace and plant mounds were investigated using tension infiltrometers in areas subjected to low and high disturbance. Multiple tension infiltration data were analyzed by non-linear regression and inverse modeling to determine the in-situ near-saturated conductivities and water retention characteristics (WRC) of the field soil.

Results indicate that, following low and high disturbances, interspace soils increased moderately in bulk density by approximately 5% and 16%, respectively. Bulk density in mound soils increased by 24% and 38% in areas with low and high impact, respectively, and penetrometer resistance increased by 40% under low impact and over 200% following high impact for both interspace and mound soils. However, near-saturated conductivities remained unaffected. It is hypothesized that disturbance resulted in a compaction of macro-porosity while increasing meso-pore structures, leaving near-saturated conductivities relatively unchanged. Inverse modeling with HYDRUS-2D further verified these results. The van Genuchten parameters of the water retention functions also validate the change to pore-size distributions, mainly effecting macro-porosity. Though near-saturated conductivities remained stable, the change in retention characteristics indicate that unsaturated conductivity in disturbed soil will decrease more rapidly than in undisturbed soil. Given that the climate at Ft. Irwin is arid, it is expected that the soil will typically remain dry, and that root water uptake and plant establishment will be more difficult. For land managers, revegetation may be limited by both penetrometer resistance restricting root growth, and lack of available water through a reduced unsaturated hydraulic conductivity.

Land degradation and it's Environmental Impact: A View of Semi-arid African Regions

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Natural factors such as water and wind (erosional agents) have been instrumental in the degrading of land. Human factors such as agricultural systems, land tenure, economic policies with man's overall developmental needs have also enhance this process in the Moungo.

Using field work techniques(questionnaires. Landuse maps, face to face discussion, direct observation), primary and secondary source data, it was discovered that, it is important to provide information on the man environment relationship. This would be useful to organisation and governments.

The paper therefore unfolds the realities that land degradation has a negative impact on man as a result of decreasing bio-diversity and other resources(water,atmosphereetc).

This paper therefore recommends planning and implementation of soil conservation practices, carrying out soils surveys, monitoring and land capability classification. If these techniques are to adhered ,poverty, food shortages, famine, droughts, desertification and other calamities can be reduced or totally alleviated.

Exploring Design Limits for Semiarid Banded Production Systems Using Ecological Optimality Considerations and a Probabilistic Approach

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There is potential for designing banded production systems that mimic the water use characteristics of natural vegetation systems and thereby reduce deep drainage and runoff from agricultural land. Alternate bands of woody perennials, herbaceous perennials and annual crops could be arranged to optimise the redistribution and storage of excess rainfall for use during dry periods. The optimisation of such designs for specific climates is a difficult exercise, but design limits can be investigated using considerations of ecological optimality and probabilistic modelling of soil water storage. For a given rainfall distribution, plant-soil loss functions and soil water storage capacities can be matched to achieve prescribed probability distributions of soil water storage. Loss functions and storage capacities outside the realms of possibility can readily be identified. Alternatively, if loss functions and storage capacities are known, approximate band widths can be determined to meet prescribed hydrologic targets.

Surface and Subsurface Flow Paths in Gullies and Arroyos in Colorado - Observations

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Gullies and arroyos in Colorado exhibit a variety of erosional features indicative of both surface and subsurface flow as active geomorphic agents. With the objective to calibrate a numerical model of sapping erosion, fieldwork in Colorado (Fort Carson and Pinion Canyon Maneuver Site) yielded a variety of observations, including permeability associated with gully morphology. These observations might show the relevance of both, surface runoff and subsurface water flow, in the mass wasting process that shapes steep walls in semi-arid landscapes, such as those observed in southeastern Colorado.

Developing Effective Ecosystem Monitoring Strategies for Military Activities in Deserts: Preliminary Results From the US Army Yuma Proving Ground

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Biomass and biodiversity in arid lands is largely associated with vegetation along tributary channels that drain alluvial fans and along alluvial washes. This lineal distribution of vegetation is due to a considerable increase in plant available water that is derived from the ephemeral runoff of precipitation generated from surrounding soils. This augmented water may be two or three times the amount of water relative to point source precipitation alone. Any change in runoff supplied water, either as a result of soil degradation related to military activities or change in seasonal precipitation related to climatic change, will directly impact critical parts of the ecosystem. Recognition of physical and biological signals that indicate change in the flux and availability of water will greatly benefit land rehabilitation and management of sensitive desert lands.

The focus of this project is designed to determine if key shrub and tree species distributed along first-order channels draining desert piedmonts on military reservations can provide cost-effective and reliable signals of environmental change and desert ecosystem health. Our approach integrates essential soil, geomorphic, hydrologic, and biologic characterization data to establish how soil surface conditions, climatic variables, and vegetation dynamics are hydrologically linked. This project is being conducted at the US Army Yuma Proving Ground (YPG) in Arizona, but the results are applicable to other Army and DoD installations in desert regions

Preliminary results indicate that trends in vegetation health along 1st order drainage channels will be sensitive to changes related to either military activities or natural changes in rainfall. Initial results suggest that a long-term (>50-year) trend in a contraction of vegetation is likely occurring. Initial results indicate that the vitality of essential tree species along desert washes may be strongly influenced by water derived from infrequent large storms. Spring and mid-summer predawn and midday water potentials achieved in Cercidium (foothills palo verde) and Olneya (desert ironwood) are much higher than could be expected given the very low volumetric moisture content of the soils (< 1m). This suggests that Cercidium and Olneya have access to deep water supplies (2-6 m, vadose zone, not ground water). It is possible that infrequent, high energy storms (the last high energy storm was in 1998) provide enough water to generate overland flow and provide sufficient recharge at deeper soil depths to sustain plant activity over prolonged periods (i.e. > 1-3 years) where ambient water inputs are not sufficient to recharge shallower surface layers. If this is indeed the case, then first order drainages in this region of the Sonoran Desert are likely more sensitive to very localized patterns of run-on augmentation than they are to large-scale drainage dynamics.

Reconsideration of Using Water Ponding Dikes to Re-establish Native Grasses in Shrub-Invaded Areas of the Southwest

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Many rangeland treatments have been tested to cause a reversal in the process of shrub invasion into desert grasslands. It seems that because of the harsh nature of the arid environment, just removal of shrubs and even subsequent seeding with native or introduced grasses is not enough to reverse the trend. Several examples are illustrated with historic aerial photography. A more integrated approach seems to be necessary and particularly one that involves the concentration of water to increase localized soil moisture. Increased soil moisture alone is not always enough as is evidenced by historic treatments where brush water spreaders and contour terraces were used, although the results of these treatments may have been different if the original treatments had been properly maintained. The relatively simple construction of water ponding dikes seems to produce the best result, and the success and persistence of the dikes appears to vary with soil type. Inexpensive to construct, these dikes require little maintenance but have produced significant results over a period of years. As was observed in nearly all dikes constructed on the Jornada Experimental Range in southern New Mexico, immediate results cannot be expected as several large rainfall-runoff events need to occur, usually over a period of years. The vegetation response of the Jornada dikes is easily seen using air photos, and the vegetation pattern produced is very similar to naturally occurring "banded vegetation". Grass response has been positive in all water-ponding dike installations, and it appears that native species in the local seedbank respond better than introduced species. Well planned installation of these simple structures over a landscape unit may initiate changes that could lead to re-establishment of grass in the desert ecosystem. Study of banded vegetation systems may generate guidelines for dike spacing on soils with similar hydrologic properties. A series of research water ponding dikes will be established in New Mexico and Arizona to test this treatment over larger areas of the Southwest.

Measuring Evapotranspiration Changes in Semiarid Pine Forests Due to Fire and Thinning

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Forested portions of semiarid land in the Western U.S. are managed for multiple uses, including water yield. Vegetative manipulation has occurred in forests of the U.S. due to the policy of excluding fire since the late 1800s. The unintended consequence of fire exclusion has been to reduce recharge to aquifers through increased interception of snowfall and increased transpiration of the much denser pine and shrub canopy. We are studying the impacts of thinning and prescribed burning on evapotranspiration of the herbaceous understory and the surrounding pine trees in an upland wet meadow at Hart Prairie, Arizona. Four treatments were randomly applied to replicated plots in herbaceous communities dominated by bracken fern or grasses (1) unaltered control, (2) repeatedly clipped to remove all vegetation, (3) burned during the pre-monsoon season, and (4) burned during the late-summer monsoon season. Treatment effects on herbaceous evapotranspiration were assessed by soil-water budgets based on repeated soil-moisture measurements with time-domain reflectometry. Comparisons between control and clipped plots in 2000 and 2001 showed that both herbaceous communities used substantial amounts of water that otherwise might be available for groundwater recharge and down gradient seep and spring ecosystems. Results for the summer of 2001 burn suggest that fire during the premonsoon period decreased herbaceous water use in the fern-dominated community, and to a lesser degree in the grass-dominated community. Transpiration of the nearby pine trees was measured separately using sapflux methods and was found to be two orders of magnitude smaller than the understory vegetation. The large increases in soil moisture from fire in the understory are short term, while the small increases in soil moisture from tree thinning are permanent.

Biotic and Abiotic Constraints on Woody Plant Seedling Establishment in Semi-Arid Savannas

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In semi-arid regions, spatial and temporal variation in soil moisture is probably the most important driver of shifts in plant distribution and abundance. High densities of grasses may deplete soil moisture resources and inhibit woody plant seedling establishment. Furthermore, soil moisture availability may also be mediated by soil texture. We investigated biotic and abiotic constraints on woody plant establishment in semi-arid savannas by constructing twenty-four 1.5m x 1.5m plots on soils with either high or low clay content. Three levels of grass density (intact, 50% removal, and 100% removal) and two levels of watering (ambient and watered) were assigned to each plot on both soil types. Mesquite (Prosopis velutina) seeds were planted in August 2001. Soil moisture was measured to a depth of 20cm using time-domain reflectometry probes. Dependent variables included soil volumetric water content and seedling emergence, recruitment, and survivorship. At the time of seedling emergence, soil volumetric water content was greater ($p<0.005$) on the high clay soil (9%) than on the low clay soil (7%) and greater ($p<0.03$) in graminoid removal plots (9%) than in intact plots (8%). All seedling response variables were inversely correlated with graminoid biomass ($p<0.0001$) and correlated with soil clay content ($p<0.0001$). Results indicate that soil moisture is mediated by both graminoid biomass and soil texture and may be the ultimate constraint on woody plant seedling establishment in semi-arid savannas.

Dry-season albedo and antecedent rainfall in the desert-savanna transition zone of West Africa

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Calibrated satellite data from 1998 to 2002 from West Africa show a 2-3% dry season albedo decrease following rainy seasons with above-average rainfall. SeaWiFS and SPOT Vegetation time series data were used to document surface reflectance variations which we found to be directly associated with greater primary production in the semi-arid zone of West Africa, where rainfall is the principal determinant of plant growth. This provides confirmation of the "Charney" hypothesis.

Predicting the Impacts of the Cerro Grande Fire on Floods, Hillslope Erosion and Channel Sediment Transport

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The May 2000 Cerro Grande Fire severely burned the headwaters of many of the canyon streams draining through the Los Alamos National Laboratory (LANL), Los Alamos County and Pueblos in Northern New Mexico. The fire increased observed flood magnitudes and hillslope erosion rates by one to two orders of magnitude above pre-fire conditions. Flooding increased scour and deposition in canyon channels that had been relatively stable over the past 50 years. A set of modeling activities were undertaken to predict the potential impacts of large and small rain events on human health, LANL facilities and infra-structure. A GIS-based hillslope erosion model was developed and applied to determine sediment inputs from burned uplands into the stream network. The HEC models were used to predict flood magnitudes, durations and inundation areas. HEC6T, a one-dimensional sediment transport model, was coupled to a contaminant model to predict potential redistribution and offsite transport of contaminated hillslope and floodplain sediments. Model predictions were calibrated against observed events. In particular, the HEC6T predictions were calibrated against high-resolution Airborne Laser Scanning (ALS) topographic data, collected before and after a 1440 cfs flash flood in a canyon contaminated with low levels of legacy Pu. The ALS data were validated with field cross-sections, and showed the spatial distribution of channel and floodplain scour and deposition throughout the canyon. These data formed the backbone of our model validation/testing process, along with observed sediment concentration data. The model performed well in predicting the zones of scour and deposition observed in the canyon for this flood event, and suggests that the HEC6T model may be a reasonable model for assessing the impacts of floods in this and other canyons in the area. Initial calibration of the hillslope model against observed sedimentation in an upland reservoir suggests the model is a reasonable predictor of erosion in the first years after the fire. On-going work aims to assess the impact of post-fire recovery on floods and sediment mobility.

THURSDAY, 12 SEPT

Oral Presentations

Assessing Impacts of Environmental Change: Why We Need to Understand Temporal Scales of Semiarid Ecohydrologic Processes

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When semiarid systems are affected by various global, regional, or local environmental changes, temporal scales of ecohydrologic processes become critical considerations when assessing the response of such systems. In this presentation, examples from different semiarid subsurface flow studies are discussed to illustrate responses of hydrologic systems to environmental change at different temporal scales. These examples demonstrate the extreme range of response times that challenge ecohydrologic researchers. Temporal scales of semiarid subsurface flow systems can be extremely long, (e.g., residence times of water in some semiarid vadose zones can exceed thousands of years), or relatively short, (e.g., groundwater recharge in other semiarid systems can occur at seasonal or even daily time scales). The subsurface movement of water in semiarid environments is strongly linked to ecologic processes such as transpiration, and subsurface flow systems can have major impacts on ecologic systems. Thus, it is important to understand the temporal scales on which semiarid ecohydrologic systems function, and what might happen to those scales when systems are perturbed (if the system is perturbed and there is a system response, does it occur on a different time scale?). Methods and approaches for assessing subsurface water flow at different temporal scales will be presented, along with a discussion of the limitations of these methods (e.g., methods of examining long time scale behavior may not be appropriate when examining short time scale behavior).

Vegetation: A Key Indicator in Identifying Dominant Hydrologic Over a Range of Scales in Water-Limited Environments

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In arid and semiarid regions ephemeral stream systems are common. Many of these streams and their associated watersheds exhibit "influent" or losing behavior where runoff volume and peak discharge decrease in a downstream direction. Influent ephemeral channel systems present an inherent challenge in using observed runoff to aid in our understanding of watershed response to rainfall whether it be for model development or parameter calibration and validation of watershed response models. In these systems the observed runoff depth (runoff volume/drainage area) is often less than the measuring accuracy of rain gauges (e.g. large noise to signal ratio). In this case, and, in most distributed model applications, we need other observations to adequately measure model performance. Observations of vegetation from in-situ and remote methods may offer a more robust, distributed measure of infiltrated storm water. Since the largest abstraction of rainfall for semi-arid thunderstorms is typically infiltration, it may be possible to calibrate and validate our watershed response models if vegetation change could be related to infiltrated rainfall depth. In essence, by taking this approach we would broaden the typical hydrologist's definition of watershed response to consider more than runoff and include vegetation response as an additional measure of watershed response to rainfall across a broader range of time scales. While influent watersheds may be the most difficult to model in terms of runoff prediction, in many instances, the response of vegetation to rainfall and infiltration in these water-limited watersheds is truly dramatic. Biomass production, particularly of perennial grasses, is highly correlated to rainfall inputs. Exploratory work is being carried out to assess whether this correlation would be significantly improved if the observed rainfall amount is adjusted to better estimate the water available for plant growth by abstracting interception, on-site runoff, and soil evaporation.

As drainage area increases in many semi-arid watersheds in the Basin and Range geological province, an abrupt transition in the watershed runoff response as a function of drainage area is observed. This abrupt change, from the tributary USDA-ARS Walnut Gulch Experimental Watershed to the larger San Pedro basin, represents a dramatic change in the processes controlling watershed response as the regional and alluvial aquifers combine to maintain sections of the San Pedro River main stem in perennial and intermittent streamflow. As in the upland case noted above, vegetation in these regions of perennial and intermittent flow is a key indicator of this abrupt change in the dominating hydrological processes.

In the non-water limited environment of the perennial riparian corridor the amount of water transpired by the riparian vegetation becomes a major factor in the overall water balance of the basin. Yet direct estimates of riparian water use (ET) on daily time scales over riparian corridor scales greater than 10 kilometers had not been attempted. To address this challenge a step-wise scaling approach to estimate riparian ET using a combination of micrometeorological techniques to estimate patch scale mesquite and sacaton grass ET; and, sapflow and isotope techniques to estimate cottonwood/willow ET at the plant and patch scale were employed. From the plant to patch scale, remote sensing and modeling techniques were employed to further scale the riparian ET observations to the reach scale (~100m) over several days, and to the corridor scale (~10 km) over a 90-day period. In this scaling approach riparian ET was estimated independently as were all other components of the riparian corridor water balance. At the corridor scale, a volume balance error of 5.2% was achieved over the 90-day period.

While this endeavor proved quite successful it also pointed out a number of intriguing plant structure-water use relationships that were significant and not readily apparent. One important factor was the change in water use of the cottonwood (Populus fremontti) willow (Salix goodingii) riparian forest complex as a function of flood controlled plant-patch dynamics. Both cottonwood and willow are pioneer species whose establishment depends on flood disturbance to provide alluvial deposits in the active channel for seed establishment. However, further establishment within intact forests is limited. As the forest patches develop and the stream channels change course, the stem densities decline and patches become dominated by a few large cottonwood and willow trees. Younger trees on the primary channel with high stem densities are more columnar in shape than older, isolated trees on secondary channels with a crowned canopy shape. The columnar shape of the younger trees translates into greater leaf area and consequently higher sap flux and stand-level transpiration. This finding has important implications for the use of multi-spectral remotely sensed data to extrapolate the riparian water use model to the corridor scale as this type of remotely sensed data is unable to differentiate between important structural differences within the cottonwood species. A combination of multi-spectral and LIDAR data may provide the necessary information to differentiate young from old patches and thus more accurately estimate corridor level riparian water needs.

Evapotranspiration from Aridland Vegetation: The Potential Role of Canopy Architecture and Morphology In Regulating ET

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Two opposing views have dominated the debate as to what controls plant transpiration – plant physiologists assume stomata play a dominant regulatory role whereas meteorologists assert that net radiation controls ET over well-watered vegetation. In an effort to balance these two viewpoints, Meinzer (TREE 8:289-294) reviewed the concept of stomatal decoupling coefficients as a function of plant canopy properties. In aridland vegetation, canopy properties may be particularly important. In general, ET can be adequately predicted if leaf area, plant water status and meteorological properties are known. However, for a given leaf area, different canopy structures may result in contrasting transpiration rates of individual canopies. In this paper, I will review three aspects of plant canopy morphology/architecture – leaf orientation, leaf pubescence, and stem photosynthesis – that are common properties of plants in dryland regions. There are also excellent data sets that show these traits to become more common, both within and across species, along aridity gradients. In each case – leaf orientation, leaf pubescence, and stem photosynthesis – it has been assumed that they are primarily adaptations to enhance photosynthesis and/or energy balance in response to drought conditions. However, comparative data sets also indicate that these properties can have important direct consequences for canopy transpiration. Therefore, in stands of dryland vegetation with open, non-continuous canopy structures, leaf and canopy architectural properties may become particularly important as parameters that need to be incorporated into predictive models of evapotranspiration at the landscape scale.

Impact of Stochastic Hydrologic Dynamics on Vegetation Structure of Water Controlled Ecosystems

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Ecohydrology is the science that studies the mutual interactions between the hydrologic cycle and ecosystems.Ecological patterns and processes are shown to be intimately linked to the hydrologic dynamics and to its intermittent and stochastic characteristics.In water controlled ecosystems the key linkage is shown to occur through the probabilistic structure of the soil water content which acts as the central interactive node between climate,soil, and vegetation. The stochastic dynamics of the hydrologic inputs is also shown to be crucially responsible for the characterization of nutrient cycles and vegetation coexistence .

Poster Presentations

Lateral and Vertical Unsaturated Flow in a Hilly Landscape in Semiarid Environment

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We modeled unsaturated water flow in a hillslope section in Upper Dry Creek, near Boise, Idaho using two-process based models, SHAW and HYDRUS2 to get insight to 1. Control of scale and model geometry, 2. Inter-model soil hydraulic model comparison for different seasons, and 3. Conditions for initiating lateral flow. The combined model results at the column, plot and hillslope scales were compared with field soil moisture content observations. We conclude that the modeling approach captured the observed patterns of moisture content during dry, wet and transitional periods although the predicted moisture content values were generally higher than observed values. Both predicted and observed moisture content increased near the surface during fall. During snowmelt, the wetting front advanced further downwards through the soil profile. The transitional period following snowmelt was characterized by upward decline in soil moisture, with both evaporation and drainage represented in the flow vector fields. We examine the correspondence between observed and predicted moisture content at pedon, plot and hillslope scales using different soil hydraulic models. The effects of hysteresis in soil moisture retention were insignificant. The pattern of moisture variability was largely dependent on whether moisture input was limiting. Quantitative model results suggest that moisture content under unsaturated conditions plays a role in vertical and lateral hydrologic connectivity of the hillslope, under specific geometry and model domain properties. Vertical flow was predominant during imbibition, once the wetting front was sufficiently far from the soil surface. Near-surface lateral flow appeared primarily during drainage. Lateral flow also occurred near the base of the soil profile above a minimum moisture content threshold. In this case, lateral flow initiated first in shallower part of the hillslope. The hillslope becomes (vertically or laterally) hydrologically connected differently at different modeling scales. However, there was no direct relationship between scale and lateral flow emergence time or flow vector magnitude. We found the combined modeling approach to be useful for visualizing the flow field that developed in a two dimensional domain under time-variant boundary conditions. The scale comparison provided useful insights into the control that two-dimensional domain geometry has on flow field representation.

Precipitation, Temperature and Vegetation Interactions in the West African Sahel: Using Canonical Correlation Analysis to Measure Covariance

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A new twenty-year AVHRR NDVI dataset at 8km resolution has been produced that has been solar zenith angle corrected, and has had noise removed. This data was used with precipitation and temperature station data to better understand the interaction between rainfall, temperature and vegetation in the West African Sahel. Estimates of long-term vegetation change were derived from the NDVI data. Canonical correlation analysis was used to determine the drivers of vegetation dynamics, including rainfall, temperature, ENSO indicies and the North Atlantic oscillation indicies, factors that are known to be important in semi-arid West Africa. The degree to which changes in vegetation can be accounted for with known factors and those that may be attributable to anthropogenic factors was determined.

Evapotranspiration responses to climate and vegetation forcing above the Middle Rio Grande riparian corridor, New Mexico

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Long-term monitoring of terrestrial ecosystem-atmosphere interactions yields a diversity of data necessary for a detailed understanding of the surface characteristics that regulate water and energy flux. Additionally, a combination of micrometeorology with plant physiological and ecological properties shows promise for scaling evapotranspiration (ET) from tower points to the corridor or basin. Eddy flux towers are in place above native and nonnative riparian vegetation types along the 320 km Middle Rio Grande corridor. Seasonal contribution from spring versus summer ET was affected by climate deviation, especially with respect to development of summer monsoon precipitation. Power spectral and wavelet analyses of high frequency time series data from 3-dimensional eddy covariance systems illustrates the regulating effects of plants upon latent but less so sensible heat fluxes. The differential effects of cottonwood, Russian olive and saltcedar stands on the energy balance of the atmospheric surface layer underscores the importance of setting and mescoscale events on local microscale water cycling.

Dynamics of Evapotranspiration in Semiarid Grassland and Shrubland during the Summer Monsoon Season, central NM

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The dynamics of ET are key to a variety of processes, including plant productivity, runoff and recharge, and land-atmosphere interactions. A primary control on the dynamics of both evaporation and transpiration (and therefore ET) is the structure of an ecosystem and how it functions. We conduct a head to head comparison of ET and surface energy balance components in semiarid grassland and shrubland ecosystems in the Sevilleta Wildlife Refuge of central New Mexico. The Bowen Ratio-Energy Balance method is used at both a grassland site and at a shrubland site. We have compared side-by-side measurements from Bowen ratio and eddy covariance methods at these sites, and the difference between the methods is negligible with respect to its effect on midday ET and evaporative fraction (EF). We present two summers of monsoon season data, which is when evapotranspiration peaks in both of these ecosystems. At both the grassland and the shrubland, values of ET and EF vary considerably throughout the season. High values (ET ~ 4 mm/day; EF ~ 0.7) are observed directly following rainfall events. However, at both locations, ET and EF return to low values (ET ~ 0.5 mm/day; EF ~ 0.1) within only a few days. This drydown is roughly exponential and time constants (t) reveal that the drydown is faster at the shrubland (tEF = 1.4 days) than at the grassland (tEF = 2.6 days). Our study also suggests that ET and EF vary linearly with surface soil moisture (q) at both the shrubland and the grassland (R2 ~ 0.8 for both EF and ET at either site). We calculate slopes (MEF = dEF/dq; MET = dET/dq) for these regression lines: EF in the shrubland increases more q (MEF ~ 4.9) than in the grassland (MEF ~ 3.5). In contrast, MET is more similar between the sites. There are two main reasons that ET is similar at both sites. First, the midday available energy (Qa) is higher at the grassland (Qa ~ 460 Wm-2) than at the shrubland (Qa ~ 380 Wm-2). Second, the evaporative fraction is more strongly controlled by soil moisture in the shrubland than the grassland. We believe the observed differences are the result of the extensive bare soil (~70%), and therefore more direct evaporation, at the shrubland

Importance of Hydrologic Controls On Nitrogen Deposition Impacts in Seasonally Dry Ecosystems - the Asynchrony Hypothesis

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The mountains of southern California receive among the highest rates of N deposition in the world (~40 kg ha-1 yr-1). These high rates of deposition have translated into consistently high levels of nitrate in some streams of the San Bernardino Mountains. However, we have identified 8 streams in the Devil Canyon watershed that have highly variable nitrate concentrations despite close proximity. Perennial streams have high nitrate concentrations (~ 200 µmoles L-1) while ephemeral streams do not (~ 20 µmoles L-1). The ephemeral streams also have a notable large flush of nitrate at the onset of flow followed by very low nitrate concentrations. These difference as well as geochemical data point to groundwater as the major source of the nitrate observed in streams during most of the year. Our results also indicate that seasonal variability of stream nitrate concentrations is in part a function of decreased riparian N retention and denitrification during the winter season rather than solely hydrologic flushing of nitrate from soil. Furthermore, the evidence indicates a disconnect between terrestrial and aquatic impacts in Mediterranean climates. The primary reason for this disconnect involves the asynchrony between when atmospheric deposition occurs (summer), the time period of maximum soil nitrate availability and leaching (winter), and the time of maximum plant N demand (spring). Our results indicate that semi-arid Mediterranean climate systems behave differently from more humid systems, in that aquatic systems may not be indicative of changes in terrestrial ecosystem response, because of this asynchrony and the importance of riparian retention and denitrification. These differences lead us to the conclusion that the extrapolation of impacts from humid to Mediterranean climates is problematic and the differences in the process level controls of N saturation is in need of further research in arid, semi-arid and seasonally dry systems.

A Non-uniform Grid Scheme for Coupling Land Surface Processes at Multiple Scales

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Land surface processes respond differently at a range of scales, depending on the sensitivity and the available information for characterizing the parameter space. An efficient multi-scale procedure for coupling land surface processes with atmospheric and subsurface has been developed. The Non-uniform Grid Scheme (NGS) utilizes hierarchical sub-grids with a high degree of characterization, and are nested within grid-matched coarser grids. Conservation of mass and momentum is maintained across the grids and aggregated fluxes are computed for the larger scale, which will bi-directionally couple to a fine-scale regional atmospheric model. Initial studies have shown a shift in the latent and sensible heating rates as the degree of land surface heteorogenity is increased. Application of the NGS to a watershed for investigation of mountain front recharge and riparian zone discharge and biogeochemical processes is being developed for the San Pedro River Basin in Arizona. We carry out a sensitivity analysis using the NOAH model, in offline fashion, driven with reanalysis and remote sensing data. Initially, a uniform grid of 4 km is used throughout the domain, then, a grid of 100 m is used for the main riparian areas and 500 m for the mountain fronts. To complete the sensitivity analysis we use a uniform grid of 1 km over the domain and a grid of 100 m over the riparian areas and the mountain fronts.

The Dynamism of Land Uses and their Effects on Water Catchment, A Contemporary Developing World Approach

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Land use activities such as changing agricultural practices, deforestation along water catchments, afforestation with damaging tree species (Eucalyptus and Cypress), cattle rearing and overgrazing, urbanization and infrastructural development, bush fires, quarrying and the application of fertilizers, chemicals and phyto-sanitary materials, have serious effects on vegetation and water catchments.

Water Pollution has become a major crisis in such a way that all the rivers and water catchments in Bui Division and Kumbo in particular are all polluted. In this regard, information to be presented, has been obtained using primary sources such as, questionnaire analysis, field observations, face-to face discussions, land use maps, unpublished documented material, and the appraisal of library source material. The acquired information has been analyzed using simple statistical techniques such as averages, percentages, degrees, Analysis of Variance, and is presented in tables, figures, maps, and descriptive writing.

The study revealed that these activities result to reduction of vegetation within Catchment areas and also to contamination of water, deposition of sediments and/or reduction in volume of water supply. This poses a serious problem both to the population and to administrative officials. In this regard, recommendations are therefore made due to the present concern about environmental issues by environmental expertise

Night-Time Vertical Fluxes of Latent Heat in Arid Regions

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The role of dew in arid and semi-arid ecosystems is considered to be of great importance. It can serve as a water source for the bacteria of biological crust, for plants and for small insects. The Negev Desert is a semiarid region characterized by winter rainfall (long term average of 115 mm per year) with a very large inter-annual variability. Reports on measurements carried out in this area mention that up to 180 nights a year with dew were registered by a conventional Hiltner Dew Balance, with intensities that ranged from 0.1 to 0.2 mm per night (yielding a total of ~15 mm per year, which is more than 10% of the total rainfall). The Hiltner dew balance is based on the continuous weighing of an artificial condensation plate that hangs from a beam 2 cm above the soil surface; hence the energy balance of its condensation plate is completely different from that of the soil surface above which it is installed. The Hiltner dew balance could, therefore, be considered as a "potential dew" gauge, whose results are probably mainly correlated to atmospheric conditions. The prime objective of this work was, therefore, to quantify the amounts of dew deposition on the soil surface (distinguished from quantities of dew condensing on artificial plates), and to estimate its contribution to the water and energy balance of bare soil in arid ecosystems.

Measurements were carried out at the Wadi Mashash Experimental Farm (31o 08' N, 34 o 53' E; 400 m.a.s.l.). To estimate deposition and evaporation of dew, a micro-lysimeter (diameter: 20 cm; soil depth: 50 cm) with an undisturbed soil sample was installed flush with the soil surface. The following were continuously monitored: micro-lysimeter weight, incoming and reflected short wave radiation, net radiation, dry and wet bulb temperatures at four levels using six automatically interchanging aspirated psychrometers, wind speed at four heights, soil heat flux, and soil temperature down to 50 cm depth in 5 cm intervals. The representativeness of the sample in the micro-lysimeter was assured by measuring sample temperature at different depths and along a cross- section. A conventional Hiltner Dew Balance was placed close by as a reference to compare with previous measurements. Throughout the period during which dew had been previously reported (mainly) spring, summer and fall), and at random intervals, soil samples were taken hourly during the whole night. The uppermost 10 cm of the soil was divided into 1 cm intervals, and the soil moisture content was measured (oven dry).

During the above-mentioned night campaigns, no dew deposition could be visually detected on the soil surface. A mass gain was, however, registered with the micro-lysimeter as well as with the Hiltner dew balance, and an increase in soil moisture content was measured. These results indicate that although no visual signs of dew deposition could be detected, moisture did penetrate into the soil. Surprisingly, these measured amounts of absorbed moisture fit fairly well with the previously reported dew deposition amounts.

Solar Radiation Interception, Microclimate, and Water Balance in Complex Terrain

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Incoming solar radiation (insolation) is the major source of energy at the earth's surface, and is a primary driver of water flux. In particular, insolation directly affects local temperature, which in turn affects evapotranspiration rates. Three components of topography determine local insolation: 1) elevation, with greater insolation at higher elevations; 2) surface orientation, with decreased insolation at larger angles of incidence; and 3) surrounding obstruction, with decreased insolation when sky obstruction increases. We are using GIS-based approaches to evaluate landscape patterns of insolation, microclimate, and water balance for the Los Alamos National Environmental Research Park and surrounding lands. Using an upward-looking viewshed insolation model (the Solar Analyst), which requires a digital elevation model (DEM) and estimates of transmittivity for input, we calculated variation in direct and diffuse insolation as a function of landcape position and time of year. Then we used an insolation-modified adiabatic model, calibrated with ground-based meteorologic measurements, to calculate climatic surfaces (temperature, precipitation, potential evapotranspiration, and actual evapotranspiration) for the study site. In keeping with findings for other topographically diverse sites, topography has a strong and predictable influence on evapotranspiration through its effect on insolation.

Coupled Water and Nutrient Cycling in Semiarid Ecosystems: the Influence of Spatial Variability of Infiltration on "Islands of Fertility"

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Shrubs have invaded extensive areas of semiarid grassland in the southwestern U.S. over the past 200 years, resulting in dramatic ecosystem changes. One critical change is that the zones of nutrient-rich soil found beneath plant canopies, referred to as "islands of fertility", are more intense and spaced further apart in shrubland than in grassland. This difference in the spatial pattern of soil nutrients, such as available nitrogen, is believed to reinforce the ecosystem changes associated with shrub invasion.

Changes in surface and vadose zone water cycling also influence the grass-to- shrub vegetation transtion. We present soil moisture and infiltration data collected from grasslands and shrublands in the Sevilleta National Wildlife Refuge. In both environments, infiltration is greater beneath plant canopies than beneath interspaces during rainfall events that yield overland flow. In the shrubland, the canopy-interspace infiltration ratio increases as storm size increases. Summed over 31 rainfall events, there is more than twice as much infiltration beneath shrub canopies than interspaces. Infiltration beneath grass canopy and interspace is roughly equal summed over the same storms. Based on this data, we propose a new model that explains why "islands of fertility" are more intense in shrubland. The key element of this model is that nitrogen mineralization occurs most rapidly when the soil is wet. In shrubland, canopy soil is wetter than interspace soil, due to the spatial variability of infiltration, canopy shading, and soil texture effects. Therefore, nitrogen mineralization is more intense beneath shrub canopies. In contrast, the soil moisture distribution in grassland promotes more spatially homogenous nutrient cycling. We test this model with laboratory soil incubations. These laboratory experiments demonstrate that soil moisture is the key control on N mineralization, not soil carbon or cover type

Water Balance Change for a Re-vegetated Xerophyte Shrub in Semiarid Area

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Water balances of a re-vegetated xerophyte shrub (*Caragana korshinskii*) community was compared to those of a bare surface area by using auto-weighing type lysimeters during the growing seasons 1990-95 at the southeast Tengger Desert, Shapotou, China. The 6-year experiment displayed how major daily water balance components varied for a bare and a vegetated sand dune area by use of weighing lysimeters. The *ET* of the *C. korshinskii* was seen to represent a major part of the water balance. On average, the *ET*/*P* ratios varied between 69-142% for the different years. No recharge was observed for the vegetated lysimeter. For the bare lysimeter, on the other hand, 48 mm or 27% of rainfall per year recharged the groundwater. Re-vegetating sandy areas of this type by xerophyte shrubs would accordingly mean that soil water storage is reduced by plant root water extraction so that virtually no groundwater recharge can occur. From a viewpoint of desert ecosystem reconstruction, however, it appears efficient, economic, and practical to use the natural rainfall to establish artificial sand-binding xerophytic shrubs of *C. korshinskii*. This, of course has to be put in view of in cases where, e.g., local population is depending on groundwater for water supply.

Hydrologic Controls on Soil Nitrogen Concentrations along an Air Pollution Gradient in a Semi-Arid Climate

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High deposition rates of atmospheric nitrogen may foster the rapid decline seen in Southern California's Coastal Sage Scrub (CSS) ecosystems as cover by native shrubs is replaced with exotic grasses. We are investigating the role of hydrologic processes may play in deposition enhanced plant invasion. We compare the movement of mobile nitrate and ammonium through the soils of two CSS sites located at the extremes of an atmospheric nitrogen depositional gradient. The first site, on the eastern edge of the South Coast Air Basin, is directly impacted by large nitrogen inputs (~30 kg N ha-1 year-1). The second site is removed from primary smog trajectories with minor nitrogen inputs (~5 kg N ha-1 year-1). We analyzed soils with depth to fresh bedrock for nitrate, ammonium, and chloride content using three cores per site per season for one year. Our results show two primary zones of nitrogen concentration in the soil: above the 25 cm depth (the primary rooting depth for annuals and grasses) and between 50 to 125 cm depths (the primary rooting depth for CSS shrubs). Primary loss of nitrogen from the soil for both zones occurs during the rainy season (late fall and winter months). Differences between the two sites is seen primarily in nitrogen concentration of the top 25 cm of soil which shows a downslope increase as the rainy season progresses. Concentrations within the root zone at both sites are similar and show no conclusive downslope increase. These results suggest that a major shift in the hydrologic response of CSS ecosystems may occurring as shrubs, and their root conduits, decrease in number. The top 25 cm of the soil may be becoming the predominate zone of water movement, with increasing amounts of exogenous nitrogen being concentrated in a decreasing depth of the soil. This suggestion is being examined by comparing soil chloride content as a conservative tracer of water movement in these soils to soil moisture data acquired using a neutron probe.

Comparative Study of Energy Flux and Evapotranspiration of Oak/grass Savanna and Grazed Grassland Under Extreme Soil Water Deficit and High Temperature

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Due to its heterogeneity and complexity, oak/grass savanna ecosystems are poorly understood by our ecologists, in term of energy and water fluxes and their response to environmental perturbations. Here we present the results from a study on seasonal variation of energy flux and evapotranspiration (ET) of an oak/grass savanna and a nearby grazed grassland under the conditions of severe water stress and extreme high temperature. The experiment site is located on the foothills of the Sierra Nevada Mountains in California. The site has a Mediterranean climate with wet, cold winter and dry, hot summer. The predominant tree species is blue oak (Quercus douglasii) and grasses of understory are C3 species. Latent heat (LE) and sensible heat (H) over- and understory of the oak/grass savanna and over the grazed grassland were measured using eddy covariance technique. Other meteorological, soil and plant physiological parameters, including solar radiation, net radiation (Rn), PAR, air temperature, soil moisture, predawn water potential, leaf area index and stomatal conductance, were also measured at different time intervals.

It was found that seasonal variations in ET over the grazed grassland and understory of oak/grass savanna followed changes in grass leaf area index (LAI), which in turn was controlled by soil moisture content. This response is due to the shallow rooting depth of grass. During the dry summer, when the grass was dead, virtually all the available energy was partitioned into H.

Seasonal changes in oak tree transpiration were obtained by subtracting overstory LE from understory LE. Transpiration decreased slowly in the dry summer and it did not follow the seasonal variation of tree LAI. Instead, stomata manage water loss by responding to severe water stress and high temperature during the summer; the leaf stomatal conductance decreased from 0.5 mol per square per second in the early summer to less than 0.05 mol per square meter per second in the fall when the predawn leaf water potential reached 7.0 MPa. Net radiation balance (Rn) over the grazed grassland peaked (around 600 W per square meter) as early, at the end of April, just before the grass senescence. While for the oak/grass savanna, Rn peaked (around 700 W per square meter) more or less around summer solstice. More than one-third of the total energy exchange was attributed to the understory throughout the season at the savanna system. Since a substantial amount of energy exchange occurs under the oak tree, multi- or two-layer models are needed as a tool to estimate energy and water vapor fluxes from this open savanna ecosystem.

Estimation of land surface evapotranspiration in the western Chinese Loess Plateau using remote sensing and GIS Techniques

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Evapotranspiration (ET), an essential component of the water balance, plays a significant role in regional and global climate through the hydrological cycle, and its calculation or estimation has important applications in assessing ground water recharge, predicting crop yield, planning land use, etc. Satellite-derived estimations of the land surface evapotranspiration in the western Chinese Loess Plateau are presented in this paper. The remote sensing approach applied is based on a feedback relationship in which the land surface parameters obtained from the satellite images, such as radiometric surface temperature, albedo, and vegetation index, are used to estimate the actual evapotranspiration.The data derived from NOAA/AVHRR and MODIS were applied within such conventional evapotranspiration models as SEBAL, PENMAN, MORTON, BUDYKO and THORNTHWAITE. The observed data in the western Chinese Loess Plateau are used to verify the estimates of input variables. Our experiments show that BUDYKO model performed best with a relative error of only 5.2% among these models. BUDYKO model was thus used to estimate the evapotranspiration of the region using the observed climatic data from 43 meteorological stations and the remotely sensed data as the input variables. Furthermore, moisture index (IM), thermal efficiency index (TE), aridity index (IA) and humidity index (IH) were also spatially calculated. Spatial regression model for each index was developed to generate regional distribution maps for each index. A spatially-synthesized and evapotranspiration-based index, namely a drought proxy, was developed. This proxy turns to be very useful in evaluating the temporal and spatial patterns of climatic suitability for specific agricultural production and also useful to provide spatially-distributed guidelines for the government to deal with drought disasters in the western Chinese Loess Plateau.

FRIDAY, 12 SEPT

Oral Presentations

The Role of Water Balance in Carbon Cycling: Are Arid Regions Different from Temperate Regions?

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Water deficits influence plant growth and mortality from cellular levels of physiology, to ecosystem scales of vegetation competition to global scales of biogeography. This array of water stress controls has been quantified in models from leaf gas exchange, to ecosystem biogeochemistry to global photosynthesis. Yet all share a common thread of water plant relations theory. This presentation will trace the application of these water relations controls from leaf to global scales, and illustrate the scaling logic required to make jumps from individual plants, to ecosystems, to continents and finally global analysis. Recently published results quantifying the role of water balance in the U.S. carbon sink strength, and of new satellite derived daily global photosynthesis will be presented.

Connections Between Vegetation and Deep Vadose Zone Hydraulics in Semiarid and Arid Environments

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Recent field studies in conjunction with multiphase flow and transport modeling of arid and semiarid vadose zones implicate desert vegetation as the key factor responsible for the unique hydraulics of thick vadose zones. A unifying conceptual model requires the role of desert vegetation in imparting and sustaining very dry conditions within the root zone and consequently serving as a buffer for the deep hydraulic regime from seasonal and longer transients in moisture conditions. Multiple lines of evidence including water potential, chloride, and nitrate profiles show distinctly different soil-water flux regimes associated with different vegetation communities in arid to semiarid climates. Active recharge (significant downward fluxes) tends to characterize the soil moisture regime beneath bare soil and mesic vegetation (e.g., piñon and juniper). In contrast, deep moisture fluxes beneath desert shrubs and grasses in nearby regions generally appear to be very small, upward, and in some cases, dominated by vapor transport. The mechanism by which some vegetation retain and utilize essentially all deep infiltration, permitting no downward fluxes for periods of thousands of years, but adjacent vegetation communities regularly permit deep fluxes, remains obscure, as does the ecological significance of the different behaviors. One specific question that arises is which came first: the dry soil moisture conditions that initiated the transition from mesic to xeric vegetation or the establishment of xeric vegetation required to impart such dry conditions? Clearly, there is much to learn about how vegetation and climate act to control desert vadose-zone fluxes.

Atmosphere-land surface interactions in semi-arid regions

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Semi-arid regions are a mosaic of different landscape types, including grasslands, shrubland, riparian forests, irrigated and non-irrigated crops, and urban areas. The surface energy and moisture fluxes from these diverse land surfaces are quite distinct. My presentation discusses these differences, and shows how the spatial variation of surface heat and moisture fluxes results in spatial variations in horizontal and vertical atmospheric transport and dispersion on the local and regional scales. The effect of anthropogenic land use change in this region will be shown to have a major influence on the regional climate. The global implication of such landscape variations will also be presented. It will be demonstrated using global model results, for example, that land use change has already had an effect on regional, and even the global climate system, that is equal to or even greater than would occur due to the radiative effect of a doubling of CO_2 concentrations. The failure to include this effect into climate simulation experiments is shown to be a serious oversight in planning for the future.

Constraints and opportunities for plant growth in water-pulse driven arid environments

Susanne Schwinning, Biosphere 2 Center, Columbia University, PO Box 689, Oracle, AZ USA 85623.

This talk reviews the results of a recent modeling exercise that examines the role of pulsed resource renewal for arid land plants. The first part focuses on the tradeoffs associated with water pulse use by plants and shows how rainfall patterns could shape the adaptations of desert plants. At the basis of the study is a hydraulic soil-plant model that simulates photosynthetic carbon gain under water-limited conditions. For simplicity, soil in the model is structured into only two layers, with spring-summer precipitation recharging only the shallow soil layer and fall-winter precipitation also recharging the deeper soil layer. Plants in the model are characterized through different allocation patterns to leaf and root biomass in the two layers, and through different physiological drought responses. Plant water uptake is linked to carbon gain through a photosynthesis model for C3 plants. Using carbon gain over some interval as a fitness proxy, the model predicts optimally adapted phenotypes for any soil moisture recharge pattern. Many of the derived phenotypes are reasonable approximations of recognized “plant functional types” (PFTs), suggesting that PFTs could be seen as specialists on particular a soil moisture pattern. In the second part of the talk, the model is taken to the next level, asking how plants with contrasting adaptations compete for soil water and interact with soil moisture dynamics. It will be shown how plant species coexist on one resource (water) and how changes in the amount and pattern of precipitation might affect plant communities. The results from this heuristic model are used to identify areas of research need.